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Oct. 12/07

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Concrete Engineers' and Contractors' Pocketbook

Prepared by the Editors of
CONCRETE ENGINEERING

Assisted by
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CLEVELAND

Perhaps the most difficult task in the preparation of this pocketbook was the selection of formulae for the use of the designer. It was our purpose to present not only formulae that all engineers must approve, that is, what may be called the long method, but also shorter formulae of more recent derivation that have been found equally true and accurate. The former we had little trouble in securing. The latter, however, promised to delay the publication of the book further and we decided not to introduce it until the second edition is printed. We will have some printed in a form convenient for loose insertion, and any purchaser of a copy of the first edition can procure one of these pamphlets without cost on request.

Extracts, original in subject matter or in form of presentation, have been liberally made, with credit in each instance, from the following standard works:

Reinforced Concrete, by Charles F. Marsh. D. Van Nostrand Co., 23 Murray and 27 Warren St., New York, publishers. Price $7.

A Treatise on Concrete, Plain and Reinforced, by F. W. Taylor and Sanford E. Thompson. John Wiley & Sons, 43-45 E. 19th St., New York, publishers. Price $5.

Architects' and Builders' Pocketbook, by Frank E. Kidder, published by John Wiley & Sons (see above). Price $5.

Reinforced Concrete, by Albert W. Buel and Charles S. Hill, published by The Engineering News Pub. Co., New York. Price $5.

The Handbooks of the Cambria Steel Co. and the Jones & Laughlins Steel Co. were also used.

The following credits were marked for correction in the plates, but the delays in the publication of this work were so many that we decided not to attempt their rectification until the second edition is published, which will necessarily be soon:

Bids Received for Steel for Concrete Reinforcement, p. 93—*Engineering News;* Comparative Costs of Concrete, p. 98—*Engineering News;* Concretes, p. 108—Edwin Thacher; Data on Beams by Prof. Talbot, p. 146—Marsh; Two Loads Applied Symmetrically to Beams, p. 151—Marsh; Maximum Permissible Tension, Shear, and Bending Moments for Bolts in Timber, p. 152—Kidder; Tensile Strengths of Cement Mortar with Natural Sand, p. 164—Baker's Masonry Construction; Tests of Slag Cement, p. 165—Marsh; Effect of Fineness of Sand on 1:2 Cement Mortar, p. 171—Baker; Comparative Tensile Strengths in lb. per sq. in., p. 173—Marsh; Transmission and Hoisting Ropes with Nineteen Wires to the Strand, p. 179—Jones & Laughlins.

INTRODUCTION.

In preparing this book we have not attempted to give tables which would enable an inexperienced person to design in reinforced concrete. To do so would, in our opinion, be questionable engineering. We have endeavored to collect such standard data as the designing engineer, the engineer contractor and the superintending engineer require for reference. In consequence we have omitted all unnecessary material, referring frequently to the most recent and best works on reinforced concrete, and the best general handbooks. We do not claim to have made tests, but we give, in the form of tables, many of the recent tests, from which a comparative study may be made. We have collected from the handbooks such data as is universally required in this kind of construction. We have prepared a special table for computing beams, which we believe has advantages over other tables. We wish to say to the reader, as a final word of caution: Unless you are certain that you have analyzed all stresses in designing your various members, **don't attempt to design in reinforced concrete.**

GENERAL NOTES.

Capt. Sewell says concrete is only affected by fire to a depth of ¼ to ¾ in., except at exposed corners where there is a tendency to rounding off 3 in. radius.

Use of flints is dangerous.

Concrete should be mixed wet when applied to the metal. Mixed too wet, concrete never attains its full strength.

To insure impermeability a concrete must be made very rich. Addition of slaked lime ensures closing of the pores. Many use soft soap or caustic potash and alum. 2 lbs. soft soap, 12 lbs. alum, and 30 gals. of water per cu. yd. of mortar.

Heads greater than 70 ft. are not advisable for large diameter concrete pipes.

Reinforced concrete is heavier than steel or iron-work for supporting the same load. There is a high percentage of dead to live load.

After the ultimate strength of the concrete is reached, its modulus of elasticity becomes nil.

On account of the monolithic nature of a structure, heavy machinery causes little or no vibration. The driving of concrete piles also shows the resistance to shocks.

Dampness causes elongation; dryness, a contraction of concrete. The richness of the mixture plays a greater part than temperature, but can be obviated by use of steel.

Stone should always be thoroughly wetted before gauging. Concrete should always be kept damp, while setting, thus allowing equal setting.

Cement should be the best, finely ground and cool. Aggregate proper size and perfectly clean. A lean, dry concrete is likely to form lines of cleavage between successive layers.

When acid or alkaline solutions are present in sand the sand should not be used.

If a steel structure must be protected with concrete, it is more economical to use reinforced concrete.

In making tests, the materials should not be too severely strained during the initial stages, as the resistance increases with the age. Most building authorities require three times the maximum load for which the structure is designed. Three months should expire before a test is made.

BEAMS.

Steel is placed in beams to assist the concrete in tension, shear and sometimes compression. Steel in concrete beams is never itself in shear.

Stirrups and the bent bar take the shear not taken by the concrete. The portion of the bent bar at the top and ends of beam takes the tension due to negative moment. The straight bars in the bottom at the center take the tension and at the ends compression. When the concrete is unable to take the entire compression, the upper straight bars are added and inverted U's are used, or bars fastened with lower bars in some manner. Steel should be placed in the tops of all roof beams and girders.

For various systems see "Reinforced Concrete," by Charles F. Marsh.

CEMENT.

Quick setting cements are generally used for pipes, reservoirs, etc. Slag cements, unless burnt after the mixing of the ground ingredients, should not be used. They are not as strong as Portland cements. Slag cements are good under water, but unfit for air.

A good brand of Portland cement passing the specifications of the American Society of Testing Materials should be used.

SAND.

Grains passing a sieve of meshes 1-5 x 1-5 in. is considered sand.

The following characteristics have been observed:

Resistance is less for mortars with regular grains.

As grains become smaller the resistance lowers.

When sand is mixed the resistance increases if there are twice as many coarse grains as fine grains, maximum being obtained by a perfectly graduated mix.

GRAVEL AND STONE.

For reinforced work it should never be larger than ¾ in. when the reinforcement is of small sectional area. When large sections are used 1¼ in. may be used. Sand should be screened out so that the materials can be properly proportioned. Stone should be free from argillaceous or organic matter.

PROPORTIONS.

The richer the mixture, the greater the compressive strength; the greater the impermeability, the greater the change in volume. It is best to proportion by weights, as cement is likely to be fluffed. See table on page 185.

Table Deduced from Dr. Dykerhoff's Tests on Cubes of Mortar and Shingle Concrete.

Proportions			Crushing Strength. Lbs. per square inch	Strength of Concrete in Terms of that of Mortar
Portland Cement	Sand	Stone		
1	2	0	2158	100
1	2	3	2783	129
1	2	5	2414	126
1	3	0	1406	100
1	3	5	1661	114
1	3	6½	1534	109
1	4	0	1068	100
1	4	5	1291	121
1	4	8½	1221	114

VOIDS.

Voids vary greatly with the humidity and method of filling. For detailed discussions, see Marsh, and Taylor & Thompson. It is advisable to test the various sands to find which one has the greatest compactness. The amount of cement and sand to make a unit volume of mortar should also be found. Mortar dropped from a trowel should leave it perfectly clean; it should be easily molded into a ball and if dropped 20 in. should retain its rounded shape without cracking.

M. Feret determined that:

(1) The compactness of a concrete increases with the size of stone.

(2) It varies inversely as the proportion of the fine grains in the mortar.

(3) It decreases generally as the proportion of the mortar to the same volume of stone increases. Table page 5.

The following table was made by Mr. Baker at Watertown Arsenal on 12 x 12 x 12 in. cubes:

Relative to Strengths of Concretes Tested 600 Days After Moulding.

Proportions of the Mortar used with the same stone		Proportion of Cement Relative	Crushing strength		Relative Strength of Last Column
Cement	Sand		Actual	Derived from Plotting results and taking the mean line	
1	1	1.00	4467	5000	1.00
1	2	0.67	3731	3300	0.66
1	3	0.50	2553	2500	0.50
1	4	0.40	2015	2000	0.40
1	5	0.33	1796	1000	0.32

The volume of mortar required to fill the voids is always more than the voids as originally measured, increasing as the stone becomes smaller and more mixed. From 9 to 15% of water should be used—of course, varying conditions must always be taken care of. Materials should always be mixed dry, and the water then added. If hand mixed, see that it is evenly mixed.

STEEL.

When the elastic limit of the reinforcing metal is passed, providing all other stresses are proportionately taken care of, the concrete beam fails; consequently it is the chief criterion. For conservative practice a tensile strength of 60,000 lb.; an elastic limit of 30,000 to 40,000 lb.; an elongation of 20% in 8 in. and bending cold 180 deg. without fracture, are fair requirements of steel.

The different patented bars have the following tensile strengths:

	Elastic Limit.	Ultimate Strength.
Ransome	36 to 50,000	60,000 to 100,000
Thacher	32,000	64,000
Johnson	50 to 60,000	100,000
Kahn	30,000	60,000

Ordinary working stresses range from 15,000 to 22,000 lb. per sq. in. in tension. Shear at 10,000 to 12,000 lb.

Lap bars 30 diameters to develop the grip.

Small bars are more expensive than large, but small bars distribute the stress better and have a greater perimeter.

REINFORCEMENT.

In a work of this kind, for the packing in small compass of tables and data for convenient reference, it is not consistent to attempt a description of the various styles of reinforcing material. The subject is too large. If treated in a helpful way it would require a book for its exposition. It is the intention of the publishers of *Concrete Engineering* to devote one issue to a description of the different kinds and systems of reinforcement at an early date.

Following is a list of names of reinforcing materials from Marsh. Nearly all are patented.

American Concrete Steel Co.; Bonna; Bordenave; Bousseron & Garric; Chaudy; Clinton; Coignet; Columbian; Cottancin; Coularou; Cummings; Degon; Demay; De Valliere-Simon & Co.; Habrich, or Thomas & Steinhoff; Hennebique; Johnson; Kahn; Klett; Koenen; Locher; Machiachini; Matrai; Melan; Moller; Monier; Mueller, Marx & Co.; Pavin de Lafarge; Piketty; Rabitz; Ransome; Roebling; Sanders; Siegwart; Stolte; Thacher; Walser-Gerard; Wayss & Freytag; Williams; Wunsch.

The Johnson bars are among the best known. The Kahn are in great vogue. The Thacher and Diamond, made by the Concrete Steel Engineering Co., are much used. The Clinton Wire Cloth Co.'s system is one of the best known, while the Unit and Hennebique are being patronized extensively. The International Fence & Fireproofing Co. makes a good form of reinforcing. Some of the recently introduced forms in America are: The Gabriel, C. A. P. Turner, Maxwell (American Concrete Steel Co.), the system of the General Fireproofing Co., and Ferro-Inclave, put out by the Brown Hoisting Machinery Co. mostly for roofing. The Trussed Concrete Steel Co., owners of the Kahn patents, have recently brought out the Cup-Bar and a style of expanded metal reinforcement.

FORMS.

Formwork depends on the type of construction, thickness of slab and consequent large dead load of slab and required alignment of the completed structure. For floors a live load of 35 lb. per sq. ft. would appear sufficient. They should be of sufficient rigidity that the vibrations are not severe enough to affect the setting of the cement. All forms should be put together so that they can be easily removed and should be made to take any swelling which may occur. This can be done by beveling one edge. Open jointed canvas lined molds are sometimes used. Dressed lumber should be used where finished surface is desired. To prevent concrete from sticking to the molds, oil, paper and tin or sheet iron are used. Where corners are likely to be broken off, bevel strips are used. Openings should be left in the bottom of columns to remove sawdust, etc. Bands are placed closer at the bottom than at the top of columns; battens used about 18 in. o. c. on beams and girders, every other one projecting 4 in. below bottoms to nail on cross piece; joists placed at each batten to brace sides of beams and girders; strips nailed along battens to support joists; bottoms of beams and girders shored. Forms can be held together by rods, wires or special devices. The span of flooring, siding, joists and shoring can be computed from the following data and tables:

EXPLANATION OF THE TABLES OF SAFE LOADS IN POUNDS, UNIFORMLY DISTRIBUTED FOR RECTANGULAR WOODEN BEAMS ONE INCH THICK, ON FOLLOWING PAGES.

(From Pocketbook of the Cambria Steel Co.)

General.

For convenience in use, three of these tables have been prepared, from which the safe loads of the various species can be obtained, either directly or by proportion as stated in the footnotes.

The values given in the tables are the safe loads in pounds uniformly distributed, including the weight of the beam itself, for rectangular beams 1 in. thick for spans from 4 to 40 ft. and for depths from 4 to 24 in. The safe load for a beam of any thickness may be found by multiplying the values given in the tables by the thickness of the beam in inches.

The last column of each of the three Tables of Safe Loads for Rectangular Wooden Beams gives a coefficient of deflection, by means of which the deflection for any beam may be obtained, corresponding to the given span and safe load, by dividing the coefficient by the depth of the beam in inches, which will give approximately the deflection in inches under the given conditions.

In each table the deflection coefficient is given for only one species of wood, as shown, but the deflections for other species may be obtained from these by proportion as explained hereafter.

For the reason that wood has no well-defined limit or modulus of elasticity the deflections obtained by the use of the coefficients are only approximate and will vary, according to the moisture content of the wood and the character of the loading. The deflections thus obtained are, therefore, useful only as a general indication of the amount of bending to be expected under the given conditions and are not exact as in the case of materials like steel, which has a well-defined limit and modulus of elasticity.*

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*Note.—"A series of tests, undertaken at the College of Forestry at Cornell University, seems to demonstrate that, at least in coniferous wood, a definite elastic limit for any particular piece can be easily shown, and, that it coincides with the theoretically calculated elastic limit upon the bases of compression tests and their application, according to Neely's formula."

The safe loads for other species of woods than those stated in the headings of the tables may be obtained from those given, by direct proportion, dependent upon the ratio of their allowable unit stress as compared with that for which the table is figured, as stated in the footnotes at the bottom of the tables.

EXPLANATION OF THE TABLE OF SAFE LOADS FOR RECTANGULAR BEAMS OF WHITE PINE, CEDAR, SPRUCE OR EASTERN FIR.

The values for the various species of woods, which are included in this table are calculated for an allowable fiber stress, for flexure, of 700 lb. per square inch.

The deflection coefficients are given for white pine, and are based upon a modulus of elasticity of 1,000,000 lb. per square inch.

The lower dotted line crossing the table indicates the limits of spans for which the deflection will exceed 1-360 of the span for the kind of wood for which the deflection coefficient is given. For spans below the line the safe loads given in the tables will produce a deflection greater than 1-360 of the span, while those above the line will produce less than this, which is the usual limit of deflection, in order to prevent cracking of plastered ceilings. Similarly, the upper dotted line indicates the limit of deflection for the kind of wood for which the deflection coefficient is given, corresponding to a modulus of elasticity of 500,000 lb. per square inch, which should be considered in cases where the deflection should be more closely limited.

The coefficient of deflection for cedar corresponding to moduli of 700,000 and 350,000 may be obtained by multiplying those of the table by 10-7 and 20-7 respectively, and for spruce and eastern fir corresponding to moduli of 1,200,000 and 600,000 by multiplying those of the table by 5-6 and 5-3 respectively.

The full zig-zag line in the table gives the limits of the safe loads corresponding to the allowable shearing stress along the neutral axis of the beam. The safe loads above the line, which are based upon the extreme fiber strains, will produce shearing stresses along the axis or with the grain in excess of that allowable, which, in the case of white pine and the other woods of this table, is 100 lb. per sq. in.

The position of this line, which indicates the limit of safe loads for shearing along the neutral axis, was determined by the aid of the following formula:

$$W = \frac{4bds}{3}$$

in which

W = safe load in pounds uniformly distributed.
d = depth of beam in inches.
b = breadth of beam in inches.
s = allowable shear in the direction of the grain in pounds per square inch.

EXPLANATION OF THE TABLE OF SAFE LOADS FOR RECTANGULAR BEAMS OF SHORT-LEAF YELLOW PINE.

The table is calculated for an allowable fiber stress, for flexure, of 1,000 lb. per square inch.

The deflection coefficients are figured for a modulus of elasticity of 1,200,000 lb. per square inch, but may be used for other moduli, after obtaining the corresponding coefficients by proportion as heretofore explained.

The lower dotted line across the table indicates the limits of spans for which the safe load will produce deflections greater than 1-360 of the length of the beam. Values above the line will give less deflection than this, and those below will give greater, based on a modulus of 1,200,000 lb. per square inch. Similarly, the upper dotted line indicates the limit of deflection corresponding to a modulus of elasticity of 600,000 lb. per square inch.

The full zig-zag line across the table indicates the limiting spans and loads based on the allowable intensity of shearing stress along the neutral axis of the beam. The values above the full zig-zag line correspond to shearing stresses greater than the allowable stress in the direction of the grain of short-leaf yellow pine, while those below the line correspond to shearing stresses less than that allowable, which, in this case, is assumed to be 100 lb. per square inch.

EXPLANATION OF TABLES OF SAFE LOADS FOR RECTANGULAR BEAMS OF WHITE OAK AND LONG-LEAF YELLOW PINE.

The table is computed for an allowable fiber stress of 1,200 lb. per square inch, for flexure, and the deflection coefficients are calculated for a modulus of elasticity of 1,500,000 lb. per square inch.

The limit for a deflection of 1-360 of the span is indicated by the lower dotted zig-zag line on the tables, the values below which correspond to deflections greater than, and those above to deflections less than, the limiting deflections. The upper dotted zig-zag line similarly indicates the limits of deflection for a modulus of elasticity of 750,000 lb. per square inch.

The lower full zig-zag line indicates the limit of allowable shearing stress along the axis corresponding to the allowable intensity, for yellow pine, of 150 lb. per square inch.

Similarly, the upper full zig-zag line indicates the limits for shearing along the axis for white Oak based on an allowable intensity of 200 lb. per square inch.

BEARING AT POINTS OF SUPPORT.

Care should be taken in designing to provide sufficient bearing at the points of support so that the allowabie intensity of compression across the grain is not exceeded.

This may be obtained, where necessary, by the use of corbels or bearing plates of harder wood arranged so as to give a large bearing area against the softer beam.

The following statements are made in Bulletin No. 12, U. S. Department of Agriculture, Division of Forestry:

RECOMMENDED PRACTICE.

"Since the strength of timber varies very greatly with the moisture contents (see Bulletin 8 of the Forestry Division), the economical designing of such structures will necessitate their being separated into groups according to the maximum moisture contents in use.

MOISTURE CLASSIFICATION.

"Class A (moisture contents, 18 per cent.)—Structures freely exposed to the weather, such as railway trestles, uncovered bridges, etc.

"Class B (moisture contents, 15 per cent.)—Structures under roof but without side shelter, freely exposed to outside air, but protected from rain, such as roof trusses of open shops and sheds, covered bridges over streams, etc.

"Class C (moisture contents, 12 per cent.)—Structures in buildings unheated, but more or less protected from outside air, such as roof trusses of barns, enclosed shops and sheds, etc.

"Class D (moisture contents, 10 per cent.)—Structures in buildings at all times protected from the outside air, heated in the winter, such as roof trusses in houses, halls, churches, etc.

"For long-leaf pine add to all the values given in the tables, except those for moduli of elasticity, tension and shearing, for Class B, 15 per cent; for Class C, 40 per cent; for Class D, 55 per cent. For the other species add to these values, for Class B, 8 per cent; for Class C, 18 per cent and for Class D, 25 per cent.

Based upon the above classification of structures, the two following tables have been figured to facilitate calcutions of allowable loads for wooden beams and columns.

Proportion of the values given in the "Tables of Safe Loads for Wooden Beams," to be used in order to obtain the safe loads for the various classes of structures referred to above.

Classes.	Yellow Pine.	All Others.
Class A	1.00	1.00
Class B	1.15	1.08
Class C	1.40	1.18
Class D	1.55	1.25

Safety factors to be applied to the values given in the table of "Strength of Solid Wooden Columns," in order to obtain the safe loads for the various classes of structures referred to above.

Classes.	Yellow Pine.	All Others.
Class A	0.20	0.20
Class B	0.23	0.22
Class C	0.28	0.24
Class D	0.31	0.25

(FROM THE POCKETBOOK
OF THE CAMBRIA
STEEL CO.)

SAFE LOAD IN POUNDS
FOR RECTANGULAR
OF WHITE PINE, CEDAR

Allowable fibre stress 700 pounds per square inch. Safety factor 6.

Safe loads for other safety factors may be obtained as follows:

Span in Feet.	Depth of Beam in Inches.											Deflection Coefficient for White Pine.
	4	5	6	7	8	9	10	11	12	13	14	V
4	311	486	700	953	1244	1575	1944	2352	2800	3286	3811	.34
5	249	389	560	762	996	1260	1556	1882	2240	2629	3049	.53
6	207	324	467	635	830	1050	1296	1569	1867	2191	2541	.76
7	178	278	400	544	711	900	1111	1344	1600	1878	2178	1.08
8	156	243	350	476	622	788	972	1176	1400	1643	1906	1.34
9	138	216	311	423	553	700	864	1046	1244	1460	1694	1.70
10	124	194	280	381	498	630	778	941	1120	1314	1524	2.10
11	113	177	255	346	453	573	707	856	1018	1195	1386	2.54
12	103	162	233	318	415	525	648	784	933	1095	1270	3.02
13	96	150	215	293	383	485	598	724	862	1011	1173	3.55
14	89	139	200	272	356	450	556	672	800	939	1089	4.12
15	83	130	187	254	332	420	519	627	747	876	1016	4.73
16	78	122	175	238	311	394	486	588	700	821	953	5.38
17	73	114	165	224	293	371	458	554	659	773	897	6.07
18	69	108	156	212	277	350	432	523	622	730	847	6.80
19	65	102	147	201	262	332	409	495	589	692	802	7.58
20		97	140	191	249	315	389	471	560	657	762	8.40
21		93	133	182	237	300	370	448	533	626	726	9.26
22		88	127	173	226	286	354	428	509	597	693	10.16
23		85	122	166	216	274	338	409	487	572	663	11.11
24			117	159	207	263	324	392	467	548	635	12.10
25			112	152	199	252	311	376	448	526	610	13.13
26			108	147	191	242	299	362	431	506	586	14.20
27			104	141	184	233	288	349	415	487	565	15.31
28			100	136	178	225	278	336	400	469	544	16.46
29			97	131	172	217	268	325	386	453	526	17.66
30			93	127	166	210	259	314	373	438	508	18.90
31			90	123	161	203	251	304	361	424	492	20.18
32			88	119	156	197	243	294	350	411	476	21.50
33			85	115	151	191	236	285	339	398	462	22.87
34				112	146	185	229	277	329	387	448	24.28
35				109	142	180	222	269	320	376	436	25.73

UNIFORMLY DISTRIBUTED BEAMS ONE INCH THICK AND SPRUCE OR EASTERN FIR.

Modulus of rupture 4 200 pounds per square inch.

New safe load = Safe load from table × $\frac{6}{\text{New factor}}$.

Span in Feet.	Depth of Beam in Inches.										Deflection Coefficient for White Pine.
	15	16	17	18	19	20	21	22	23	24	V
9	1944	2212	2498	2800	3120	3457	3811	4183	4571	4978	1.70
10	1750	1991	2248	2520	2808	3111	3430	3764	4114	4480	2.10
11	1601	1810	2044	2291	2552	2828	3118	3422	3740	4073	2.54
12	1458	1659	1873	2100	2340	2593	2858	3137	3428	3733	3.02
13	1346	1531	1729	1938	2160	2393	2638	2896	3165	3446	3.56
14	1250	1422	1606	1800	2056	2222	2450	2689	2939	3200	4.12
15	1167	1328	1499	1680	1872	2074	2287	2510	2743	2987	4.73
16	1094	1244	1406	1575	1755	1944	2144	2353	2571	2800	5.38
17	1029	1171	1322	1482	1652	1830	2018	2214	2420	2635	6.07
18	972	1106	1249	1400	1560	1728	1906	2091	2286	2489	6.80
19	921	1048	1183	1326	1478	1637	1806	1981	2165	2358	7.58
20	875	996	1124	1260	1404	1556	1715	1882	2057	2240	8.40
21	833	948	1070	1200	1337	1481	1633	1793	1959	2133	9.26
22	795	905	1022	1145	1276	1414	1559	1711	1870	2036	10.16
23	761	866	977	1096	1221	1353	1491	1637	1789	1948	11.11
24	729	830	937	1050	1170	1296	1429	1569	1714	1867	12.10
25	700	796	899	1008	1123	1244	1372	1506	1645	1792	13.13
26	673	766	865	969	1080	1197	1319	1448	1582	1723	14.20
27	648	737	833	933	1040	1152	1270	1394	1524	1659	15.31
28	625	711	803	900	1003	1111	1225	1344	1469	1600	16.46
29	603	687	775	869	968	1073	1183	1298	1419	1545	17.66
30	583	664	749	840	936	1037	1143	1255	1371	1493	18.90
31	565	642	725	813	906	1004	1106	1214	1327	1445	20.18
32	547	622	703	787	877	972	1072	1176	1286	1400	21.50
33	534	603	681	764	850	943	1039	1141	1247	1358	22.87
34	515	586	661	741	826	915	1009	1107	1210	1318	24.28
35	500	569	612	720	802	889	980	1076	1176	1280	25.73
36	486	553	624	700	780	864	953	1046	1143	1244	27.22
37	473	538	608	681	759	841	927	1017	1112	1211	28.75
38	460	524	592	663	739	819	903	991	1083	1179	30.32
39	449	511	576	646	720	798	880	965	1055	1149	31.94
40	438	498	562	630	702	778	858	941	1029	1130	33.00

SAFE LOADS IN POUNDS
FOR RECTANGULAR
OF SHORT-LEAF

Allowable fibre stress 1000 pounds per square inch. Safety factor 6.

Safe loads for other safety factors may be obtained as follows:

Span in Feet.	Depth of Beam in Inches.											Deflection Coefficient. V
	4	5	6	7	8	9	10	11	12	13	14	
4	444	694	1000	1361	1778	2250	2778	3361	4000	4694	5444	.40
5	356	556	800	1089	1422	1800	2222	2689	3200	3756	4356	.63
6	296	463	667	907	1185	1500	1852	2241	2667	3130	3630	.90
7	254	397	571	778	1016	1286	1587	1921	2286	2683	3111	1.23
8	222	347	500	681	889	1125	1389	1681	2000	2347	2722	1.60
9	198	309	444	605	790	1000	1235	1494	1778	2086	2420	2.03
10	178	278	400	544	711	900	1111	1344	1600	1878	2178	2.50
11	162	253	364	495	646	818	1010	1222	1455	1707	1980	3.03
12	148	231	333	454	593	750	926	1120	1333	1565	1815	3.60
13	137	214	308	419	547	692	855	1034	1231	1444	1675	4.23
14	127	198	286	389	508	643	794	960	1143	1341	1556	4.90
15	119	185	267	363	474	600	741	896	1067	1252	1452	5.63
16	111	174	250	340	444	563	694	840	1000	1174	1361	6.40
17	105	163	235	320	418	529	654	791	941	1105	1281	7.23
18	99	154	222	302	395	500	617	747	889	1043	1210	8.10
19	94	146	211	287	374	474	585	708	842	988	1146	9.03
20	89	139	200	272	356	450	556	672	800	939	1089	10.00
21	85	132	190	259	339	429	529	640	762	894	1037	11.03
22	81	126	182	247	323	409	505	611	727	854	990	12.10
23	77	121	174	237	309	391	483	585	696	816	947	13.23
24		116	162	227	296	375	463	560	667	782	907	14.40
25		111	160	218	284	360	444	538	640	751	871	15.63
26		107	154	209	274	346	427	517	615	722	838	16.90
27		103	148	202	263	333	412	498	593	695	807	18.23
28		99	143	194	254	321	397	480	571	671	778	19.60
29			138	188	245	310	383	464	552	648	751	21.03
30			133	181	237	300	370	448	533	626	726	22.50
31			129	176	229	290	358	434	516	606	703	24.03
32			125	170	222	281	347	430	500	587	681	25.60
33			121	165	215	273	337	407	485	569	660	27.23
34			118	160	209	265	327	395	471	552	641	28.90
35			114	156	203	257	317	384	457	537	602	30.63

Safe loads for any fibre stress may be readily obtained from this table by proportion.

UNIFORMLY DISTRIBUTED,
BEAMS ONE INCH THICK,
YELLOW PINE.

Modulus of rupture 6 000 pounds per square inch.

New safe load = Safe load from table × $\frac{6}{\text{New factor}}$.

Span in Feet.	Depth of Beam in Inches.										Deflection Coefficient. V
	15	16	17	18	19	20	21	22	23	24	
9	2778	3160	3568	4000	4457	4938	5444	5975	6531	7111	2.03
10	2500	2844	3211	3600	4011	4444	4900	5378	5878	6400	2.50
11	2273	2586	2919	3278	3646	4040	4455	4889	5343	5818	3.03
12	2083	2370	2676	3000	3343	3704	4083	4481	4898	5333	3.60
13	1923	2188	2470	2769	3085	3419	3769	4137	4521	4923	4.23
14	1786	2032	2294	2571	2865	3175	3500	3841	4198	4571	4.90
15	1667	1896	2141	2400	2674	2963	3267	3585	3919	4267	5.63
16	1563	1778	2007	2250	2507	2778	3062	3361	3674	4000	6.40
17	1471	1673	1889	2118	2359	2614	2882	3163	3458	3765	7.23
18	1389	1580	1789	2000	2228	2469	2722	2988	3265	3556	8.10
19	1316	1497	1690	1895	2111	2339	2579	2830	3094	3368	9.03
20	1250	1422	1606	1800	2006	2222	2450	2689	2939	3200	10.00
21	1190	1354	1529	1714	1910	2116	2333	2561	2799	3048	11.03
22	1136	1293	1460	1636	1823	2020	2227	2444	2672	2909	12.10
23	1087	1237	1396	1565	1744	1932	2130	2338	2556	2783	13.23
24	1042	1185	1338	1500	1671	1852	2042	2241	2449	2667	14.40
25	1000	1138	1284	1440	1604	1778	1960	2131	2351	2560	15.63
26	962	1094	1235	1385	1543	1709	1885	2068	2261	2462	16.90
27	926	1053	1189	1333	1486	1646	1815	1992	2177	2370	18.23
28	893	1016	1147	1286	1433	1587	1750	1921	2099	2286	19.60
29	862	981	1107	1241	1383	1533	1690	1854	2027	2207	21.03
30	833	948	1070	1200	1337	1481	1633	1793	1959	2133	22.50
31	806	918	1036	1161	1294	1434	1581	1735	1896	2065	24.03
32	781	889	1003	1125	1253	1389	1531	1681	1837	2000	25.60
33	758	862	973	1091	1215	1347	1485	1630	1781	1939	27.23
34	735	837	944	1059	1180	1307	1441	1582	1728	1882	28.90
35	714	813	917	1029	1146	1270	1400	1537	1677	1829	30.63
36	694	780	894	1000	1114	1235	1361	1494	1633	1778	32.40
37	676	769	868	973	1084	1201	1324	1453	1589	1730	34.23
38	658	749	845	947	1056	1169	1289	1415	1547	1684	36.10
39	641	729	828	923	1028	1140	1256	1379	1507	1641	38.03
40	625	711	803	900	1003	1111	1225	1344	1469	1600	40.00

Safe loads for beams of California Redwood, ⅚ of above.

SAFE LOADS IN POUNDS
FOR RECTANGULAR
OF WHITE OAK AND

Allowable fibre stress 1200 pounds per square inch. Safety factor 6.

Safe loads for other safety factors may be obtained as follows :

Span in Feet.	Depth of Beam in Inches.											Deflection Coefficient.
	4	5	6	7	8	9	10	11	12	13	14	V
4	533	833	1200	1633	2133	2700	3333	4033	4800	5633	6533	.38
5	427	667	960	1307	1707	2160	2667	3227	3840	4507	5227	.60
6	356	556	800	1089	1422	1800	2222	2689	3200	3756	4356	.86
7	305	476	686	933	1219	1543	1905	2305	2743	3219	3733	1.18
8	267	417	600	817	1067	1350	1667	2017	2400	2817	3267	1.54
9	237	370	533	726	948	1200	1481	1793	2133	2504	2904	1.94
10	213	333	480	653	853	1080	1333	1613	1920	2253	2613	2.40
11	194	303	436	594	776	982	1212	1467	1745	2048	2376	2.90
12	178	278	400	544	711	900	1111	1344	1600	1878	2178	3.46
13	164	256	369	503	656	831	1026	1241	1477	1733	2010	4.06
14	152	238	343	467	610	771	952	1152	1371	1610	1867	4.70
15	142	222	320	436	569	720	889	1076	1280	1502	1742	5.40
16	133	208	300	408	533	675	833	1008	1200	1408	1633	6.14
17	125	196	282	384	502	635	784	949	1129	1325	1537	6.94
18	119	185	267	363	474	600	741	896	1067	1252	1452	7.78
19	112	175	253	344	449	568	702	849	1011	1186	1375	8.66
20	107	167	240	327	427	540	667	807	960	1127	1307	9.60
21	102	159	229	311	406	514	635	768	914	1073	1244	10.58
22	97	152	218	297	388	491	606	733	873	1024	1188	11.62
23	93	145	209	284	371	470	580	701	835	980	1136	12.70
24	89	139	200	272	356	450	556	672	800	939	1089	13.82
25	85	133	192	261	341	432	533	645	768	901	1045	15.00
26		128	185	251	328	415	513	621	738	867	1005	16.22
27		123	178	242	316	400	494	598	711	835	968	17.50
28		119	171	233	305	386	476	576	686	805	933	18.82
29		115	166	225	294	372	460	556	662	777	901	20.18
30		111	160	218	284	360	444	538	640	751	871	21.60
31		108	155	211	275	348	430	520	619	727	843	23.06
32			150	204	267	338	417	504	600	704	817	24.58
33			145	198	259	327	404	489	582	683	792	26.14
34			141	192	251	318	392	475	565	663	769	27.74
35			137	187	244	309	381	461	549	641	747	29.40

Safe loads for beams of Douglas Fir, Red Pine (Norway Pine), Cypress, Chestnut and California Spruce, ⅚ of above.

UNIFORMLY DISTRIBUTED, BEAMS ONE INCH THICK, LONG-LEAF YELLOW PINE.

Modulus of rupture 7 200 pounds per square inch.

New safe load = Safe load from table × $\frac{6}{\text{New factor}}$

Span in Feet.	Depth of Beam in Inches.										Deflection Coefficient. V
	15	16	17	18	19	20	21	22	23	24	
9	3333	3793	4281	4800	5348	5926	6533	7170	7837	8533	1.94
10	3000	3413	3858	4320	4813	5333	5880	6453	7053	7680	2.40
11	2727	3103	3503	3927	4376	4848	5355	5867	6412	6982	2.90
12	2500	2844	3211	3600	4011	4444	4900	5378	5878	6400	3.46
13	2308	2626	2964	3323	3708	4103	4523	4964	5426	5908	4.06
14	2143	2438	2752	3086	3438	3810	4200	4610	5038	5486	4.70
15	2000	2276	2569	2880	3209	3556	3920	4302	4702	5120	5.40
16	1875	2133	2408	2700	3008	3333	3675	4033	4433	4800	6.14
17	1765	2008	2267	2541	2831	3137	3459	3796	4149	4518	6.94
18	1667	1896	2141	2400	2674	2963	3267	3585	3819	4267	7.78
19	1579	1796	2027	2274	2533	2807	3095	3396	3712	4042	8.66
20	1500	1707	1927	2160	2407	2667	2940	3227	3527	3840	9.60
21	1429	1625	1835	2057	2292	2540	2800	3073	3359	3657	10.58
22	1364	1552	1752	1964	2188	2424	2678	2933	3206	3491	11.62
23	1304	1484	1675	1878	2093	2319	2557	2806	3067	3339	12.70
24	1250	1422	1606	1800	2006	2222	2450	2689	2939	3200	13.82
25	1200	1365	1541	1728	1925	2133	2352	2581	2821	3072	15.00
26	1154	1313	1482	1662	1851	2051	2262	2482	2713	2954	16.22
27	1111	1264	1427	1600	1783	1975	2178	2390	2612	2844	17.50
28	1071	1219	1376	1543	1719	1906	2100	2305	2519	2743	18.82
29	1034	1177	1329	1490	1660	1839	2028	2225	2432	2648	20.18
30	1000	1138	1284	1440	1604	1778	1960	2151	2351	2560	21.60
31	968	1101	1243	1394	1553	1720	1897	2082	2275	2477	23.06
32	938	1067	1204	1350	1504	1667	1838	2017	2217	2400	24.58
33	909	1034	1168	1309	1459	1616	1785	1956	2137	2327	26.14
34	882	1004	1133	1271	1416	1569	1729	1898	2075	2259	27.74
35	857	975	1101	1234	1375	1524	1680	1844	2013	2194	29.40
36	833	948	1070	1200	1337	1481	1633	1793	1909	2133	31.10
37	811	923	1041	1168	1301	1441	1589	1744	1906	2076	32.86
38	789	893	1014	1137	1267	1404	1547	1698	1856	2021	34.66
39	769	875	988	1108	1234	1368	1508	1656	1809	1969	36.50
40	750	853	963	1080	1203	1333	1470	1613	1763	1920	38.40

Safe loads for beams of Hemlock, ⅚ of above.

SAFE LOAD IN LB. FOR WHITE PINE AND SPRUCE POSTS—(ROUND AND SQUARE.)—(*Kidder.*)

Size of Post in in.	Length of Post in Feet								
	8	10	12	14	15	16	18	20	24
4x6........	11520	10550	9800	8700					
5½ round.	12350	11730	11180	10490					
6x6........	19080	18216	17352	16490	16050	15620			
6x8........	25440	24290	23140	21980	21400	20830			
6x10.......	31800	30360	28920	27480	26760	26040			
7½ round.	24220	23380	22540	21660	21260	20820			
8x8........	35450	34300	33150	32000	31420	30850	29700		
8x10.......	44320	42480	41440	40000	39280	38560	37120		
8x12.......	53180	51450	49730	48000	47140	46270	44544		
9½ round.	40000	39000	37860	36800	36230	35730	34670		
10x10......	62500	55400	53960	52520	51800	51080	49640	48200	
10x12......	75000	66480	64800	63000	62160	61300	59570	57840	
10x14......	87500	77560	75600	73500	72520	71510	69500	67480	
11½ round	64930	58390	57140	55800	55170	54550	53100	51950	
12x12......	90000	90000	79780	78000	77180	76320	74590	72860	69400
12x14......	105000	105000	93170	91050	90050	89000	87020	85000	80900
12x16......	120000	120000	106300	104000	102900	101700	99400	97150	92500
14x14......	122500	122500	110350	108350	107400	106400	104460	102300	98400
16x16......	160000	160000	160000	143870	142590	141570	139260	136960	132360
18x18......	202500	202500	202500	202500	183060	181760	179170	176580	171400
20x20......	250000	250000	250000	250000	250000	250000	224500	221200	215200

SAFE LOAD IN LB. FOR OAK AND NORWAY PINE POSTS—(ROUND AND SQUARE.)—(*Kidder.*)

Size of Post in ins.	Length of Post in Feet								
	8	10	12	14	15	16	18	20	24
4x6........	13680	12600	11520						
5½ round.	14700	13900	13160	12370					
6x6........	22680	21600	20520	19440	18900	18360			
6x8........	30240	28800	27360	25920	25200	24480			
6x10.......	37800	36000	34200	32400	31500	30600			
7½ round.	28900	27850	26780	25720	25190	24660			
8x8........	42240	40768	39360	37880	37120	36480	35000		
8x10......	52800	50960	49200	47360	46400	44600	43760		
8x12.......	63360	61152	59040	56830	55680	54720	52500		
9½ round.	47960	46440	45160	43740	43100	42400	41120		
10x10......	75000	66000	64200	62400	61500	60600	58800	57000	
10x12......	90000	79200	77040	74880	73800	72720	70560	68400	
10x14......	105000	92400	89880	87360	86100	84840	82320	79800	
11½ round	77925	69820	68160	66490	65770	64833	63170	61600	
12x12......	108000	108000	95040	92880	91700	90700	88560	86400	82080
12x14......	126000	126000	110800	108300	107000	105840	103300	100802	95760
12x16......	144000	144000	126700	123800	122300	120900	118000	115200	109400
14x14......	147000	147000	147000	129300	128100	127000	124400	121900	116800
16x16......	192000	192000	192000	192000	170500	168900	166100	163000	157400
18x18......	243000	243000	243000	243000	243000	217000	213800	210600	204100
20x20......	300000	300000	300000	300000	300000	300000	267600	264000	256000

SAFE LOAD IN LB. FOR YELLOW PINE AND OREGON PINE POSTS (ROUND AND SQUARE.)*—(*Kidder.*)

Size of Post in ins.	Length of Post in Feet								
	8	10	12	14	15	16	18	20	24
4x6........	18200	16800	15300						
5½ round.	19530	18 60	17550	16500					
6x6........	30200	28800	27400	25900	25200	24500			
6x8........	40300	38400	36500	34600	33600	32600			
6x10.......	50400	48000	45600	43200	42000	40800			
7½ round.	38540	37130	35710	34300	33590	32890			
8x8........	64000	54400	52500	50600	49600	48600	46700		
8x10.......	80000	68000	65600	63200	62000	60800	53400		
8x12.......	96000	81600	78700	76800	74400	73000	70100		
9½ round.	70960	61970	60190	58350	57429	56580	54800		
10x10......	100000	100000	85600	83200	82000	80800	78400	76000	
10x12......	120000	120000	102700	99800	98400	97000	94100	91200	
10x14......	140000	140000	119800	116500	114800	113100	109800	106400	
11½ round	103900	103900	90912	88730	87690	86550	84160	82290	
12x12......	144000	144000	144000	123800	122400	121000	118100	115200	109440
12x14......	168000	168000	168000	144500	142800	141100	137800	134400	127680
12x16......	192000	192000	192000	165100	163200	161300	157400	153600	145920
14x14......	196000	196000	196000	196000	179900	169100	165800	162400	155800
16x16......	25 000	256000	256000	256000	229100	225300	221400	217600	209900
18x18......	32 000	324000	324000	324000	324000	289400	285100	280800	272160
20x20......	400000	400000	400000	400000	400000	400000	356800	352000	342400

*These two woods appear to be of about equal strength for posts exceeding 12 diameters in height.

SAFE LOAD FOR TEXAS PINE POSTS (ROUND AND SQUARE.)—(*Kidder.*)

Size of Post in ins.	Length of Post in Feet								
	8	10	12	14	15	16	18	20	24
4x6........	15500	14280	13050						
5½ round.	16650	15790	14900	14030					
6x6........	25704	24480	23256	22032	21420	20808			
6x8........	34272	32640	31008	29376	28560	27744			
6x10.......	42840	40800	37760	36720	35700	34680			
7½ round.	32740	31540	30340	29140	28540	27940	26740		
8x8........	47870	46240	44600	42970	42160	41340	39710		
8x10.......	59840	57800	55760	53720	52700	51680	49640		
8x12.......	71808	69360	66910	64460	63240	62000	59560		
9½ round.	54150	52650	51150	49580	48820	48070	46570		
10x10......	85000	78800	72760	70720	69700	68680	66640	64600	
10x12......	102000	89760	87300	84860	83640	82400	80000	77500	
10x14.. ...	119000	104700	101860	99000	97580	96150	93300	90400	
11½ round	88290	79100	77250	75400	74470	73550	71700	69850	61160
12x12......	122400	110160	107700	105260	104040	102800	100360	97920	93000
12x14......	142800	128520	125660	122800	121380	119950	117100	114240	108520
12x16......	163200	146880	143600	140350	138720	137080	133800	130560	124030
14x14......	166600	166600	149450	146600	145180	143760	140900	138080	132400
14x16......	190100	190400	170800	167500	165900	164300	161000	157800	151300
16x16......	217600	217600	217600	194700	193000	191400	188200	184900	178400

Maximum Span for Floor Joists in Dwellings, Tenements and Grammar School Rooms with Fixed Desks—(Kidder.)

Total Load, 60 pounds per square foot.

Size of Joists	Dist. on Centers	Hemlock		White Pine		Spruce or Norway Pine		Oregon or Texas Pine		Georgia Pine	
	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.
2x6..........	12	9	9	9	10	10	5	10	10	11	7
2x6..........	16	8	9	8	10	9	6	9	10	10	6
3x6..........	12	11	1	11	2	12	0	12	5	13	4
3x6..........	16	10	1	10	2	10	10	11	2	12	1
2x8..........	12	12	11	13	1	13	11	14	5	15	6
2x8..........	16	11	9	11	10	12	8	13	1	14	1
3x8	12	14	9	14	11	16	0	16	6	17	8
3x8..........	16	13	6	13	7	14	6	15	0	16	2
2x10.........	12	16	2	16	4	17	5	18	0	19	4
2x10.........	16	14	9	14	10	15	9	16	4	17	7
Total Load, 66 pounds per square foot.											
3x10.........	12	18	0	18	1	19	3	20	0	21	6
3x10.........	16	16	3	16	5	17	7	18	2	19	6
2x12.........	12	18	10	19	0	20	3	20	10	22	6
2x12.........	16	17	2	17	3	18	4	19	0	20	6
3x12.........	12	21	6	21	8	23	2	24	0	25	9
3x12.........	16	19	7	19	8	21	1	21	9	23	0
2x14.........	12	22	0	22	2	23	8	24	4	26	3
2x14.........	16	20	0	20	1	21	0	22	2	23	10
2½x14.......	12	23	8	23	10	25	6	26	3	28	3
2½x14.......	16	21	6	21	8	23	2	23	10	25	8
3x14.........	12	25	4	25	4	27	1	28	0	30	1
3x14.........	16	23	0	23	0	24	7	25	4	27	4

About 10 days should elapse before striking forms. The sides of beams can be removed sooner. It is best to keep the bottoms and shores under beams and girders for at least 5 weeks.

FACING AND FLOOR FINISH.

Facing can be applied next to the forms in the shape of a dry mortar and the backing then placed; washed with a grout, stuccoed, tooled or chemically treated. Mineral colors not over 10% by volume can be used. A ¾ in. finish (never less) can be applied to a structural floor by means of a joint made by scrubbing the floor with acid. Cork floats are used in rubbing walls.

Maximum Span for Ceiling Joists—(Kidder.)

Total Load, 20 pounds per square foot.

Size of Joists	Dist. on Centers	Hemlock		White Pine		Spruce or Norway Pine		Oregon or Texas Pine		Georgia Pine	
	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.
2x4..........	12	9	3	9	5	10	1	10	5	11	2
2x4..........	16	8	5	8	6	9	1	9	5	10	1
2x6..........	12	14	0	14	1	15	1	15	7	16	8
2x6..........	16	12	8	12	10	13	8	14	2	15	2
2x8..........	12	18	8	18	10	20	1	20	9	22	4
2x8..........	16	17	0	17	2	18	4	18	11	20	5
2x8..........	20	15	9	15	10	17	0	17	6	18	10
Total Load, 24 pounds per square foot.											
2x10..........	12	22	0	22	2	23	8	24	5	26	4
2x10..........	16	20	0	20	2	21	7	22	3	23	10
2x10..........	20	18	6	18	8	20	0	20	7	22	2
2x12..........	12	26	5	26	8	28	5	29	4	31	7
2x12..........	16	24	0	24	2	25	10	26	8	28	8
2x12..........	20	22	3	22	5	24	0	24	8	26	8

CRACKS—SHRINKAGE.

Cracks are due to the cement being unsound, concrete setting in air, mortar flushed to the surface by troweling, and changes in temperature. When large areas are considered, contraction joints should be provided. Concrete thoroughly reinforced with metal can elongate .0018 before it cracks, or a fall of temperature of 250 deg. Concrete at 200 lb. in tension and elastic limit of steel at 55,000 lb. then the area of steel required would be 1-275 of the number of square inches in the wall.

Coefficient of expansion of concrete 1:2:4 is 0.0000055 per deg. F.

Coefficient of expansion of concrete as determined by Prof. William D. Pence, University of Purdue.

Results of Experiments Made by Prof. Wm. D. Pence, Perdue University, to Determine Coefficient of Expansion of Portland Cement Mortar.

Proportions of Concrete	No. of Tests	Maximum	Minimum	Average
1:2:4 Broken stone	7	0.0000057	0.0000052	0.0000055
1:2:4 Shingle	5	0.0000055	0.0000052	0.00000535

Coefficient of expansion of wrought iron is 0.0000068.

Coefficient of expansion of steel is 0.0000067.

Concrete in tension is more variable than concrete in compression. This is due to the adhesion between the cement and the aggregate.

Well made concrete of 1:2:4 mix at the age of 1 month runs from 2,000 to 4,000 lb. per sq. in. when tested in the form of 4 in. cubes. 1:1:3 cinder cubes, 1,000 lb. A working value ranges from 500 to 750 lb. per sq. in.

Prof. Hatt found concrete to be able to stand 300 lb. per sq. in. in tension. In reinforced work the tension of the concrete is neglected.

Shear of concrete can be figured from 50 to 65 lb. per sq. in. This is lower than that given by Feret; it is about what M. Considere gives.

Prof. Bach obtained the following table from the equation $E_c = \frac{E_p}{p(n-1)}$ (See Marsh, Page 225, for detailed description.)

A mortar of 1:1½ has the greatest strength. Table on page 28.

RESULTS OBTAINED IN TESTS BY PROF. BACH ON ELASTICITY OF CONCRETE UNDER COMPRESSION.

Proportions of Ingredients in Test Pieces					Value Given by Prof. Bach for Formula $\lambda=\frac{1}{E_p}p^n$		Values of c–p in Pounds per Square Inch									
							114	228	342	456	570	684	798	912	1026	1140
Cement	Danube Sand	Egginge Sand	Broken Stone	Danube Shingle	n	E_p Lbs. per sq. in.	Corresponding Values of $\frac{E_c}{10^6}$ in Lbs. per sq. in. from Formulu $E_c - \frac{E_p}{p^{(n-1)}}$									
1					1.09	4 63x10⁶	2.94	2.77	2 67	2.60	2.53	2.50	2.47	2.44	2.42	2.39
1	1.5				1.11	6 79x10⁶	4 02	3.73	3.57	3.45	3.36	3.31	3.26	3.20	3.16	3.13
1	3				1.15	6.69x10⁶	3.28	2.96	2.79	2.66	2.56	2.50	2.44	2.40	2.36	2.32
1	4.5				1.17	5.13x10⁶	2.29	2.03	1.89	1.80	1.72	1.68	1.63	1.61	1.58	1.55
1	2.5			5	1.14	6.16x10⁶	3.17	2.87	2.71	2.62	2.52	2.46	2.42	2.37	2.33	2.30
1		2.5	5		1.16	9.96x10⁶	4.66	4.17	3.91	3.74	3.59	3.49	3.41	3.35	3.28	3.23
1	5			6	1.14	5.79x10⁶	2.97	2.70	2.54	2.45	2.36	2.32	2.27	2.23	2.19	2.20
1	3		6		1.16	8 28x10⁶	3.87	3.47	3.26	3.11	2.99	2.91	2.83	2.77	2.73	2.68
1	5			10	1.16	4.73x10⁶	2.22	1.98	1.85	1.78	1.70	1.66	1.62	1.58	1.57	1 56
1		5	10		1.20	8.90x10⁶	3.44	3.00	2.76	2.62	2.49	2.40	2.33	2.27	2.22	2.20

Coefficients for First Loading of Concrete.—(Marsh.)

Proportions of Mortar or Concrete	Age Days	Coefficient
1:2, 1:3 and 1:4	720 to 729	5.15×10^6
1:2:2 and 1:2	239	3.50×10^6 to 2.92×10^6
1:2:2 and 1:2:3	192 to 208	2.35×10^6
1:2:2—1:2:3 and 1:3	69 to 84	2.20×10^6

Considere advocates 2,700,000 lb.

Results Deduced by Prof. Hatt from Tests made at Watertown Arsenal on Elasticity of Concrete Under Compression.

Proportions of the Concrete			Age	E_c	Stress Where Measured Lbs. per sq. inch.	Crushing Stress lbs. per sq. in.
Cement	Sand	Stone				
1	2	4	9 days	1.66×10^6	1000	1944
1	2	4	3 months	3.46×10^6	1000	2200
1	2	4	6 months	4.50×10^6	1000	3500
1	3	6	9 days	1.95×10^6	1000	2308
1	3	6	3 months	3.75×10^6	1000	2500
1	3	6	6 months	2.81×10^6	1000	3500

These tests made on cylinders 8 in. in diam. and 12 in. high show that broken stone concrete has a greater E_c than gravel or cinder concrete.

$\frac{E_f}{E_c}$ varies from 10 to 15, the latter being used in calculations.

Results of Prof. Hatt's Experiments to Determine Elasticity of Concrete.

Age—Days	E_t	Elongation at Rupture, 1 part in	Strength in lbs. per sq. in.
35	2.7×10^6	11660	300
33	2.4×10^6	8750	305
28	1.4×10^6	4400	360
26	1.9×10^6	7700	280
Average	2.1×10^6	7000	311

The adhesion of concrete to the steel can be taken at 300 lb. per sq. in. Prof. Hatt made the following determinations:

Results of Prof. Hatt's Adhesion Tests of Concrete and Iron.

Diameter of Rod in Inches	Age of Specimen in Days	Depth of Rod in Concrete, Inches	"Adhesion" in Pounds per Square Inch of Surface in Contact		
			Maximum	Minimum	Average
7-16	32	72	735	470	636
⅝	35	76	780	714	756

Prof. Talbot made 32 tests.

Prof. Talbot's Tests on Resistance of Bars.

		Plain	Johnson	Remarks
Pounds per square inch of surface	Maximum	360	639	All Plain rods pulled out in no case resisting beyond the elastic limit of the metal. The Johnson bars did not slip, but in every case the concrete split or broke before failure.
	Minimum	174	298	
	Average	281	484	

Prof. W. H. Warren, Sidney University. See table page 31. It seems well to use bars slightly rusted.

COLUMNS.

Concrete columns unreinforced or reinforced with longitudinal rods only will break suddenly with very slight deformation. Failures occur in hooped columns when the deformation amounts to a value as high as 3% of the original length. A plain column does not give a warning of its failure; a reinforced one does by beginning to flake. The resistance of hooped concrete can be considered constant after it has reached a maximum. The elastic limit is raised when a load is placed on a hooped column. Hoops, according to Considere, begin to act when the longitudinal bars have passed their elastic limit and almost reached their ultimate strength.

Concrete elongates under water and contracts in air, according to the following deductions of Considere. (For detailed description, see Marsh.) Tables on page 32.

The deformation is less for reinforced than for plain prisms. The metal contracted when in air and the concrete just the reverse.

SLABS.

Slabs fail generally by the cracking of the concrete on the tension side and slipping of reinforcement through the concrete caused by the rods stretching locally. With expanded metal both fail at the same time. The compression side begins to flake at failure.

WARREN'S TESTS ON ADHESION OF CONCRETE TO STEEL.

Description	Composition				Age in days	Adhesion in pounds per square inch of surface	
	Cement	Sand	¾ Shivers	Water per cent.			
Bars with natural skin on Hardened in air	1	3		12	45	216.5	mean 198
	1	3		12	45	221.0	
	1	2	2	10	45	181.5	
	1	2	2	10	45	170.0	
Bars cleaned with emery paper Hardened in air	1	3		12.5	45	118.0	mean 125
	1	3		12.5	45	72.0	
	1	2	2	10	44	154.0	
	1	2	2	10	44	155.0	
Bars cleaned with emery paper Hardened in water	1	3		12	45	154.0	mean 185
	1	3		12	45	191.0	
	1	2	2	10	45	204.0	
	1	2	2	10	45	191.0	

BEHAVIOUR OF PRISMS WHILE SETTING UNDER WATER.—(*Marsh.*)

Elongations in $\frac{1}{100,000}$ of the original length

Number of Days After Molding		1	2	3	4	5	6	7	14	21	28	35	42	49	56	63
Neat Cement	Plain	7	15	21	27	32	37	41	59	69	73	75	77	78	78	79
	Reinforced	2	3	4	5	6	8	9	13	16	18	20	21	22	22	22
Mortar	Plain	3	10	13	15	17	18	19	20	22	24	26	27	27	27	28
	Reinforced	2	2	2	3	3	3	4	4	4	4	5	5	5	5	6

BEHAVIOUR OF PRISMS WHILE SETTING IN AIR.—(*Marsh.*)

Contractions in $\frac{1}{100,000}$ of the original length

Number of Days After Molding		1	2	3	4	5	6	7	14	21	28	35	42	49	56	63
Neat Cement	Plain	60	58	57	58	60	64	70	95	110	118	123	128	130	131	132
	Reinforced	6	9	12	14	16	17	20	22	23	24	25	25	25	25	25
Mortar	Plain	22	21	20	21	22	26	29	38	42	44	45	47	47	49	50
	Reinforced	4	6	7	8	9	9	9	9	10	10	10	10	10	10	10

BEAMS.

Rectangular beams fail by cracking on the tension side, the diagonal tensile stresses being more marked near supports. The neutral axis rising changes the original compressive stresses to tensile and finally a flaking of the upper portion of the beam takes place. Shearing stresses will, however, sometimes cause the cracks to have an inclination from the supports to the center of the beam. The proper placing of U's to take the shearing stresses not taken by bent bars and concrete will prevent this.

In T beams

$$M_r = cBh^2$$

$$V_r = c_2 b[h - a]$$

M_r = Moment of Resistance

V_r = Resistance to Shear

For discussion of beams see Buel & Hill, Taylor & Thompson, and Marsh.

FOR REFERENCE.

Diameter multiplied by 3.1416 equals circumference.

Circumference multiplied by .3183 equals diameter.

Radius multiplied by 6.2831 equals circumference.

Square of the diameter multiplied by .7854 equals area.

Diameter multiplied by .8862 equals side of equal square.

Area of a rectangle equals length multiplied by breadth.

Doubling the diameter of a circle increases its area four times.

Side of a square multiplied by 1.128 equals diameter of circle of equal area.

Surface of a sphere equals square of diameter multiplied by 3.1416.

Area of a triangle equals base multiplied by one-half the altitude.

Area of a sector of a circle equals one-half the length of the arc multiplied by the radius of the circle.

1 cu. ft. of water weighs 62 1-3 lb. and contains 7½ gals.

1 gal. of water (U. S. Standard) weighs 8 1-3 lb.

To find the capacity (U. S. gallons) of cylindrical tanks, square the diameter expressed in inches, multiply by the length and by .0034.

The pressure of still water in lb. per sq. in. against the sides of any pipe, channel or vessel of any shape whatever is due solely to the "head" or height of the level surface of the water above the point at which the pressure is considered, and is equal to .43302 lb. per sq. in. or 62.355 lb. per sq. ft. for every foot of head.

THINGS TO KNOW.

(1) The tensile value of concrete is about 1-10 the compressive value. Tetmajir's formula:

$$T = \frac{\text{Compressive Strength.}}{8.64 + 1.8 \text{ log. of age in mo.}}$$

(2) Concrete in mass is 1-50 the cost of steel, and reinforced concrete about 1-30, volume for volume.

(3) Steel will support 10 times the load on concrete when the same sectional area is considered.

(4) The cost of concrete in compression is 6-10 that of steel 1, on the average. This is approximate.

(5) By properly mixing the sizes of broken stone or gravel the voids can be reduced 20%.

(6) Compressive strength of concrete depends on the proportion of cement to sand in the mortar. (See page 39).

These can be found by Thachers formulae:

7 day old equals $1800-200 \left(\frac{\text{Volume of sand}}{\text{Volume of cement}}\right)$
1 mo. old equals 3100-350 "
3 mo. old equals 3820-460 "
6 mo. old equals 4900-600 "

Ultimate Compressive Strength of Concrete as Determined by Thacher's Formulas.

Mixture	Age			
	7 days	1 month	3 months	6 months
1:1 :3	1600	2750	3360	4300
1:2 :4	1400	2400	2900	3700
1:2½ :5	1300	2225	2670	3400
1:3 :6	1200	2050	2440	3100
1:3½ :7	1100	1875	2210	2800
1:4 :8	1000	1700	1980	2500
1:5 :10	800	1350	1520	1900
1:6 :12	600	1000	1060	1300

Compressive Strength of Concrete as Determined by Tests Made at Watertown Arsenal in 1899.

Brand of Cement	Compressive Strength lb. per sq in.			
	7 days	1 mo.	3 mo.	6 mo.
Mixture 1:2:4—				
Atlas	1387	2428	2966	3953
Alpha	904	2420	3123	4411
Germania	2219	2642	3082	3643
Alsen	1592	2269	2608	3612
Average	1525	2440	2944	3904
Mixture 1:3:6—				
Atlas	1050	1816	2538	3170
Alpha	892	2120	2355	2750
Germania	1550	2174	2486	2930
Alsen	1438	2114	2349	3026
Average	1232	2063	2432	2969
Mixture 1:6:12—				
Atlas	594	1090	1201	1583
Alpha	564	1218	1257	1532
Germania	759	987	963	815
Alsen	417	873	844	1323
Average	583	1042	1066	1313

(7) That the modulus of elasticity of concrete can be taken at 3,000,000 if a 1:2:4 mixture is considered. See tables on pages 36 and 37.

(8) That the adhesion between metal and concrete has run from 500 to 700 lb. per sq. in., making a working value of 100 to 140 lb.

(9) That when we say $\frac{E_s}{E_c}=15$

we mean that the concrete will be deformed 15 times as much as the steel if the same intensity per square inch of material is obtained.

Modulus of Elasticity of Concrete as Determined by Tests Made at Watertown Arsenal in 1899.

Brand of Cement	Modulus of Elasticity Between Loads of 100 to 600			
	7 days	1 month	3 months	6 months
Mixture 1:2:4—				
Atlas................	2778000	3125000	4167000	3125000
Alpha................	....	2083000	4167000	3125000
Germania...........	2500000	....	3571000	4167000
Alsen	2500000	2778000	2778000	4167000
Average.........	2592000	2662000	3670000	3646000
Mixture 1:3:6—				
Atlas................	1677000	3125000	2778000	3571000
Alpha................	....	2083000	3571000	4167000
Germania...........	2273000	2273000	2778000	3125000
Alsen	1667000	2273000	2778000	3571000
Average.........	1869000	2438000	2976000	3608000
Mix. 1:6:12—				
Atlas................	....	1316000	1136000	1786000
Alpha................	....	1667000	1786000	1923000
Germania...........	....	961000	2083000	1786000
Alsen	....	1562000	1562000	1786000
Average.........	....	1376000	1642000	1820000

(10) That the coefficient of expansion of concrete varies from 0.00000545 to 0.0000067 per deg. F. and that of steel 0.00000617 to 0.00000676.

(11) Invisible cracks appear in the concrete when the ultimate strength of the concrete in tension is reached.

(12) That the moment in a beam varies with the following variations in loading, as contained in Buel & Hill's formulae:

For a beam supported at both ends and loaded at the center with a load W................ $M = Wl \div 4$

Moduli of Elasticity of Concrete as Determined by Formulae Deducted from Watertown Tests.

Mixture	Age			
	7 days	1 month	3 months	6 months
1:1 :3	2600000	2900000	3600000	3600000
1:2 :4	2600000	2600000	3600000	3600000
1:2½:5	2250000	2450000	3350000	3600000
1:3 :6	1900000	2300000	3100000	3360000
1:3½:7	1550000	2150000	2850000	3300000
1:4 :8	1200000	2000000	2600000	3000000
1:5 :10	500000	1700000	2100000	2400000
1:6 :12	....	1400000	1600000	1800000

For a beam supported at both ends and uniformly loaded .... $M = Wl \div 8$

For a beam fixed at one end and loaded at the other with a load W...................... $M = Wl$

For a beam fixed at one end, unsupported at the other, and uniformly loaded................ $M = Wl \div 8$

For a beam fixed at one end and supported at the other and loaded at the center........ $M = 3Wl \div 16$

For a beam fixed at both ends and loaded uniformly .... $M = Wl \div 12$

For a beam fixed at both ends and loaded at the center .... $M = Wl \div 8$

For a beam supported at both ends and loaded with a single load, W, distant M inches from one end and n inches from the other end... $M = Wmn \div l$

Any two loads, W_1 and W_2, m inches apart, c to c W_1 being equal to or greater than W_2, will produce the maximum bending moment when the distance from W_2 to the nearest support is

$$n \text{ inches} = \frac{l - m}{2} - \frac{W_1 m}{2W_1 + W_2}$$

and the reaction at the opposite support will be

$$R = [W_2 n + W_1(m+n)] \div l$$

and the maximum moment $M = R[l - (m+n)]$

(13) Whenever designing a beam and using a T section do not deviate more than 1-6 the clear span on either side of the slab for your compression, and then the floor steel should be transverse to the beam. Do not exceed one-half the distance between beams.

(14) Do not specify high carbon steel. It is likely to crack in bending, or being heated have a section of weakness.

(15) That we may consider 60 ib. per sq. in. a safe value to use for shear of concrete.

(16) That the concrete takes a value of shear equal to the breadth of beam times the effective depth of the beam.

(17) That longitudinal shear between steel and concrete is expressed by $U = \frac{V}{moq'}$

$V =$ total vertical shear at the section given.
$M =$ no. of bars.
$o =$ periphery of bar..
$q' =$ effective depth.
$U' =$ bond developed per unit area of surface of bar.

When the bars are bent up the value of q' varies.

For detailed discussion see Buel & Hill, page 74.

(18) The distance from center of rods to edge of beam should not be less than 2 diameters of the rod.

(19 The maximum diagonal tensile unit stress is

$$t = \frac{1}{2} m^s + \sqrt{\frac{1}{4} s^2 + v^2} \quad \text{(See Merriman 1905).}$$

$s =$ horizontal tensile stress in concrete.
$v =$ horizontal or vertical shearing unit stress.

The direction of the maximum diagonal tension is represented by one-half the angle whose cotangent is $\frac{1s}{2v}$ if there is no tension in the concrete $t = v$.

(20) According to M. Considere the percentage of steel to use for static loads is 2.5; for moving loads, 1.2.

(20) That the advantages of reinforcing arches are the following, as given in Buel & Hill's Reinforced Concrete:

"Almost at the beginning of his work in reinforced concrete, Mr. Thacher perceived that the shearing stresses in an arch were practically negligible, and that, therefore, the web of the Melan ribs could safely be omitted with a considerable saving in metal. He secured a patent embodying this principle, and at the present time more Thacher arches are being built in America than any other one kind.

The advantages gained by reinforcing concrete arches with steel are:

(1) In long spans the thickness of the ring can be made very much less, thus reducing the dead load and effecting a saving of 50 per cent or more in the cost of the ring.

(2) The load being reduced, the thrust is correspondingly less, and the abutments may be very much smaller.

(3) Reinforced with steel, the working unit stresses in concrete can be considerably increased with perfect safety.

(4) The danger of cracks occurring from any cause can be prevented by the proper distribution of the reinforcing metal.

(5) Arch rings of such forms and proportions that the bending moments would render them impossible with any ordinary masonry, can be, and have been, constructed of reinforced concrete both easily and successfully.

(6) Much longer spans are practical for any given set of conditions than could be seriously considered with any other class of masonry."

(21) That it is cheaper to build a ⊥ shaped retaining wall properly reinforced than a solid concrete or counterfort wall.

(22) Lay sheeting horizontal; use from ⅞ to 2 in. stock and studding placed 2 ft. o. c. for ⅞ in. and 5 o. c. for 2 in. sheeting.

(23) Keep cement from getting wet or being in a moist atmosphere.

(24) Four men ought to mix and wheel 10½ batches of 1:2½:5 mix consisting of 4 bags Portland cement, 9.5 cu. ft. sand and 19 cu. ft. of stone—50 ft. in 10 hours.

Safe Strength of Portland Cement Concrete in Direct Compression.—(Taylor & Thompson.)

Proportions	Pounds per sq. in	Tons per sq. ft.
1:2:4	410	29
1:2½:5	360	25
1:3:6	325	23
1:4:8	260	18

With a large mass foundation take values one-eighth greater. With a vibrating or pounding load take one-half these values.

(25) The table on page 39, from Taylor & Thompson is safe for the strength of Portland cement concrete in direct compression.

(26) That Taylor & Thompson discuss the choice of mixture relative to cost on pages 43, 44 and 45, and give the tables on pages 41 and 42 following.

(27) That various cements are composed of the following ingredients. Table on page 43.

(28) That fine grinding makes a cement which is stronger tested with sand; weaker neat; quicker setting; produces larger volume of paste, and is less affected by free lime. Tables on pages 44, 45 and 46.

(29) That the quantity of water for cement pastes can be deduced from Feret's formula:
Plastic Mortars.

$$W_P = \frac{2}{3}\frac{P}{s+1} + 6.0$$

Dry Mortars.

$$W_D = \frac{2}{3}\frac{P}{s+1} + 4.5$$

W = percentage of water for mortar in terms of weight of the mixture of dry materials.

P = percentage of water required for neat cement of normal consistency.

S = parts of sand by weight to 1 part cement.

(30) The setting of cements can be tested by means of a wire 1-12 in. in diam. loaded to ¼ lb. by observing when the same is supported without leaving an indentation. (See Taylor & Thompson).

(31) If a Portland cement passes the boiling test its ultimate soundness is assured.

DESIGN.

In design the following working stresses can be taken with safety if the conditions here specified are observed when the concrete is placed.

(1) That the cement has passed the specifications of the American Society for Testing Materials. (See page 114 for complete specifications).

(2) That the sand is clean and sharp and does not contain loam exceeding 10% of the total volume.

(3) That the stone is a durable crushed stone or equally good gravel.

(4) That these are mixed in the proportion of 1:2:4 by volume.

PRICES OF PORTLAND CEMENT TO PRODUCE MORTAR OR CONCRETE OF EQUAL COST TO THAT FROM NATURAL CEMENT AT $1.00 PER BARREL.—(*Taylor & Thompson.*)

Proportions of Natural Cement Mortar	Proportions of Portland Cement Mortar							Proportions of Natural Cement Concrete	Proportions of Portland Cement Concrete				
	1:1	1:1½	1:2	1:2½	1:3	1:3½	1:4		1:2:4	1:2½:5	1:3:6	1:4:8	1:5:10
	$	$	$	$	$	$	$		$	$	$	$	$
1:1	1 00	1 23	1 46	1 69	1 92	2 15	2 38	1:2:4	1 00	1 15	1 32	1 67	2 01
1:1½		1 00	1 18	1 37	1 55	1 74	1 92	1:2½:5		1 00	1 14	1 44	1 72
1:2			1 00	1 15	1 30	1 46	1 61	1:3:6			1 00	1 26	1 51
1;2½				1 00	1 13	1 26	1 39						
1:3					1 00	1 12	1 23						

NOTE.—When the Natural cement is higher or lower than $1.00 per barrel, multiply its cost by the figures in the table to obtain approximate corresponding cost of Portland cement with which it is compared. Values make no allowance for difference in strength or labor of laying mortar.

RELATIVE ECONOMY OF DIFFERENT PRICED PORTLAND CEMENTS.—(D. M. Andrews.)

No. of Sample Barrel	Price per Barrel	Relative Cheapness	Fineness		Time of Setting		Tensile Strength						§Relative Strength of 1:3 Mortar	Rel. Economy 1:3 Mortar. Strength X Cheapness	Remarks
					Initial	Final	Neat			1:3 Mortar					
			No. 50 sieve	No. 100 sieve	Hours	Hours	7 days	30 days	60 days	7 days	30 days	60 days	60 days	60 days	
1	$2 77	100.0	93.3	87.6	2	8	324	437	430	66	128	168	79.7	79.7	
2	2 79	99.3	99.3	87.3	8‡	8‡	282	429	468	62	103	124	59.1	58.7	
3	2 82	98.2	98.2	89.7	2	3¼	272	373	431	35	65	87	41.2	40.5	Air pat cracked very slightly
4	2 82	98.2	100.0	99.6	5	9¼	369	460	564	144	184	209	99.4	97.7	
5†	2 89	95.8	99.0	86.2	7¼	7¼	449	543	631	114	175	210	100.0	95.8	
6	2 90	95.5	94.6	77.0	4	6¼	150	227	264	25	57	90	42.8	40.9	Lumpy and gritty on mixing
7	2 93	94.5	100.0	90.0	4	8	440	588	568	127	156	202	96.2	90.9	
8	3 02	91.7	99.5	89.4	2¼	7	418	476	561	89	134	174	82.4	75.6	
9	3 05	90.8	98.5	91.2	3½	7¼	4 6	518	502	93	126	144	68.2	62.0	Pats cracked slightly
10	3 29	84.2	99.4	92.7	2½	5	365	496	573	78	117	141	67.1	56.5	

†Accepted in preference to No. 4 because air pat slightly defective.
‡Cement not yet set. §Based on the highest. No. 5, as 100.0.

TYPICAL ANALYSIS OF CEMENTS—(*Taylor & Thompson.*)

	Portland cement		Natural Cement							Common Lime	
			American		Eng.	French					
	Lehigh Valley (mixed rock)	Western (marl and clay)	Eastern Rosendale	Western Louisville	Roman	Vassy	Grappiers	Puzzolan Cement	Hydraulic Lime (Le Tiel)	Lime	Magnesian Lime
Silica SiO_2	21.31	21.93	18.38	20.42	25.48	22.60	26.5	28.95	21.70	1.03	1.12
Alumina Al_2O_3	6.89	5.98	15.20	4.76	10.30	8.90	2.5	11.40	8.19	1.27	0.68
Iron Oxide Fe_2O_3	2.53	2.35		3.40	7.44	5.30	1.5	0.54	0.66		
Calcium Oxide CaO	62.89	62.92	35.84	46.64	44.54	52.69	63.0	50.29	60.70	97.02	58.51
Magnesian Ox. MgO	2.64	1.10	14.02	12.00	2.92	1.15	1.0	2.96	0.85	0.68	39.69
Sulphuric Acid SO_3	1.34	1.54	0.93	2.57	2.61	3.25	0.5	1.37	0.60		
Loss on Ignition	1.39	2.91	3.73	6.75	3.68	6.11	5.0	3.39	12.20		
Other constituents	0.75		11.46	3.74	1.46			0.30	0.10		

RECOMMENDED AM. SOC. C. E.—AMERICAN SIEVES—(*Taylor & Thompson.*)

U. S. Standard					Metric Equivalents			
No. of sieve	Meshes per linear inch	Meshes per square inch	Diam. of wire, inches	Width of openings, inches	Meshes per cm.	Meshes per sq. cm.	Diam. of wire, mm.	Width of openings, mm.
100	100	10000	0.0045	0.0045	39	1550	0.114	0.140
200	200	40000	0.0024	0.0026	79	6200	0.061	0.066

FRENCH SIEVES.

French Standard				English Equivalents			
Meshes per cm.	Meshes per sq. cm.	Diam. of wire, mm.	Width of openings, mm.	Meshes per linear inch	Meshes per square inch	Diam. of wire, inches	Width of openings, inches
18	324	0.20	0.36	46	2120	0.0078	0.0124
30	900	0.15	0.18	76	5780	0.0059	0.0071
70	4900	0.05	0.09	178	31680	0.0020	0.0035

EFFECT OF REGRINDING COARSE PARTICLES AND OF SUBSTITUTING SAND.

(*David D. Butler.*)

Cement, how treated	Fineness residue per cent on sieves of meshes per linear inch			Setting properties		Tensile strength in pounds per square inch									
						Neat cement					1 part cement to 3 parts sand				
	180	76	50	Initial set min.	Final set min.	7 days	28 days	3 months	6 months	12 months	7 days	28 days	3 months	6 months	12 months
As received..........	33.7	15.5	4.6	13	90	504	580	641	702	717	194	262	354	404	421
Reground	1.3	0.0	0.0	2	20	497	478	518	489	504	326	411	531	591	618
Sand substituted for coarse particles...						414	480	606	660	702	164	217	290	354	387

Tensile Strength of Mortar Affected by Fineness of Cement.—(Eliot C. Clarke.)

Portland Cement			Rosendale Cement		
Proportions of Cement to Sand	Strength in Pounds per square inch		Proportions of Cement to Sand	Strength in Pounds per square inch	
	Ordinary Cement 35 per cent Retained on No. 120 Sieve	Finely Ground Cement 12 per cent Retained on No. 120 Sieve		Coarse Cement 17 per cent Retained on No. 50 Sieve	Fine Cement 6 per cent Retained on No. 50 Sieve
1:0	403	304	1:0	98	92
1:3	105	180	1:1½	29	41
1:5	68	96	1:2	16	25

(5) That the forms will permit no settling, thus preventing the breaking of the adhesion between the cement and steel.

(6) That the steel is placed in the prescribed position.

(7) That the forms are not removed in less than 10 days and the bottoms of beams and girders and shoring underneath in not less than 4 weeks. In very long girders and thick slabs, not less than 6 weeks.

(8) Make the material as homogeneous as possible.

(9) Use 30 to 50 diameters to develop the grip of the bar, and if not able to do so, hook the bar at ends with a 6 in. hook.

(10) Always see that the shear is provided for when concentrated loads occur.

(11) See that you have enough area in compression, and if not, add steel and inverted U's.

(12) Always provide steel for negative bending moment.

(13) Provide shrinkage bars around all openings and in all concrete place steel for shrinkage equal to 1-275 of the total area per sq. ft.

(14) Try to use bars not larger than one inch, as too large bars do not distribute the stresses through the concrete as well as small bars.

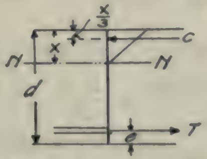
(15) In designing high buildings be sure to investigate for wind bracing.

STRESSES.

$$\frac{E_f}{E_c}=15$$

Concrete: Compression = 600 lb. per sq. in. in columns.
Diagonal Tension 60 lb. per sq. in. in beams.
Compression, average 300 lb. per sq. in. in beams.
Steel: Patented or twisted bar:
Tension = 20,000 lb. per sq. in.
Shear = 12,000 lb.
Compression = 10,000 lb. per sq. in. (round bars).

The neutral axis of a reinforced concrete slab can be found from the following:



d = thickness of slab.
c = distance center of steel to bottom of slab.
x = distance from top of slab to the neutral axis.
N-N = neutral axis.

The total compressive stresses are applied at a point $\frac{x}{3}$ below the top of the slab. In all computations slabs are generally figured for a width of $b = 12$ in.

The maximum intensity of stress in tension is f_s in lb. per sq. in.

The maximum intensity of stress in compression is f_c in lb. per sq. in.

The total area of steel required per 12 in. of breadth is A_s

The total compression $=$ $c = \frac{f_c \cdot x\ b}{2}$

The total tension $= T = A_s \cdot f_s$

The total compressive stresses are equal to the total tensile stresses and as the tensile value of the concrete is neglected $C = T$.

$$\therefore \frac{f_c \cdot x \cdot b}{2} = A_s \cdot f_s \qquad (1)$$

According to the laws of elasticity the relative deformations on a fiber depend on the distance that fiber is from the neutral avis. Then, representing the unit elongation of the street in tension by D_s and the unit compression of the extreme fiber of the concrete by D_c we get

$$D_c : x :: D_s : (d-e-x) \qquad (2)$$

But $D_c = \frac{f_c}{E_c}$ **and** $D_s = \frac{f_s}{E_s}$ $\qquad D_c = \frac{2f_s \cdot A_s}{b \cdot x \cdot E_c}$

Substituting in (2) $\frac{2f_s \cdot A_s}{b \cdot x \cdot E_c} : x :: \frac{f_s}{E_s} : (d-e-x)$

$$\therefore \frac{2f_s \cdot A_s\,(d-e-x)}{b \cdot x \cdot E_c} = \frac{x \cdot f_s}{E_s}$$

$n = \frac{E_s}{E_c}$ **and** $\frac{2A_s \cdot (d-e-x)}{b} = \frac{x^2}{n}$

$$\therefore\ x^2 + \frac{2A_s\,n}{b} \cdot x = \frac{2A_s\,n}{b}(d-e)$$

$$\therefore x = \frac{n \cdot A_s}{b}\left[\sqrt{1+\frac{2b(d-e)}{n \cdot A_s}} - 1\right]$$

This equates to $x = 1.25\,A_s\left[\sqrt{1+\frac{1.6(d-e)}{A_s}} - 1\right] \qquad (3)$

Now if $\frac{E_s}{E_c} = 15$; $f_c = 600$ and $f_s = 20{,}000$ (Using twisted steel or patented bar.)

Substituting in (2) $\frac{f_c}{E_c} : x :: \frac{f_s}{E_s} : (d-e-x)$ (4)

and $600 : x :: \frac{20{,}000}{15} : (d-e-x)$

$$\therefore x = \frac{(d-e)}{3.22} \qquad (5)$$

By proper tests E_s and E_c can be determined for the material to be used and working values of f_s and f_c obtained. These values substituted in (4) will give a different value of x.

To determine the value of $(d-e)$ substitute the value of (x) in the equation

$$f_c = \frac{2M}{b.x.(d-e-\frac{x}{3})}$$

which if $f_c = 600$ lb. per sq. in.
$b = 12$ in.
$x = \frac{d-e}{3.22}$

$$600 = \frac{2M}{12.\frac{d-e}{3.22}\left[d-e-\frac{d-e}{3(3.22)}\right]}$$

$$\frac{8.66\,(d-e)^2}{31.11} = \frac{M}{3600} \qquad \therefore d-e = \sqrt{\frac{31.11 \times M}{8.66 \times 3600}}$$

$$\therefore d-e = .0318\sqrt{M} \qquad (6)$$

Compression=Tension, then $\frac{f_c \cdot x}{2}.\, b = A_s\, .\, f_s$ using 20,000 lb. per sq. in. on the steel.

$$\frac{600\,.\,x \times 12}{2} = A_s\,.\,20{,}000 \qquad \therefore A_s = \frac{3600}{20{,}000} \cdot x = \frac{9}{50} \cdot x$$

$$\text{but } x = \frac{d-e}{3.22} \qquad \therefore A_s = \frac{d-e}{3.22} \times \frac{9}{50} = .05d-e$$

$$A_s = .056\ d-e \tag{7}$$

Representing the required area of the steel per 12 in. of breadth by A_s and that of the bar to be used as A, then the spacing of the bars is equal to

$$\frac{12 \,.\, A}{A_s} \tag{8}$$

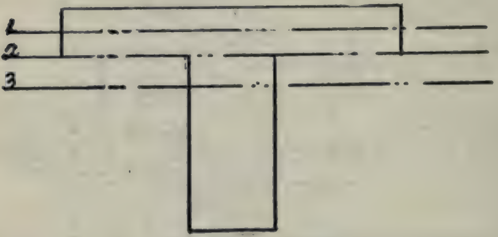
It must be remembered, however, that the spacing of the bar must not exceed 2½ (d-e).

In computaing beams as a T section we will consider it safe to have b equal to 1-3 the clear span; that is, if the span is 15 feet, then $b = \frac{15\text{x}12}{3} = 6)$

In no case should this exceed the distance between beams.

There are three cases to be considered:

(1) The neutral axis is within the slab.
(2) The neutral axis is at the bottom of the slab.
(3) The neutral axis cuts the web.



CASE I.

t = slab thickness.
x = distance to neutral axis.
d = total height of beam and slab.
b_1 = width of web.

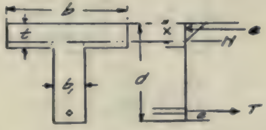
e = distance from bottom of beam. to center of steel.

A_s = area steel required.

f_c = compressive value of the concrete

f_s = tensile value of steel.

$$n = \frac{E_s}{E_c}$$



Then:

$$x = \frac{n.A_s}{b}\left[\sqrt{1+\frac{2b(d-e)}{n.A_s}}-1\right] \tag{2}$$

$$f_c = \frac{2M}{b.x.\left(d-e-\frac{x}{3}\right)} \tag{3}$$

$$f_s = \frac{M}{A_s\left(d-e-\frac{x}{3}\right)} \tag{4}$$

CASE II.

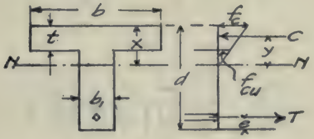
Formulae same as Case I, substituting value t for that of x.

CASE III.

Generally when the neutral axis falls below the bottom of the slab the compressive value of the concrete between the bottom of the slab and the neutral axis is neglected.

$C=\frac{f_c+f_{cu}}{2} \cdot t \cdot b \quad T=A_s \cdot f_s$ and as $T=C$

$f_c :: f_{cu} = x :: x-t$ and $f_{cu}=f_c \cdot \frac{x-t}{x}$



$$\frac{D_c}{D_f}=\frac{x}{d-e-x}$$

$\frac{f_c}{E_c} : x = \frac{f_s}{E_s} : (d-e-x)$ and since $\frac{E_f}{E_c}=n$

$\frac{f_c}{x}=\frac{f_s}{n(d-e-x)} \therefore f_s = n . f_c \cdot \frac{d-e-x}{x}$

Substituting values for f_s and f_{cu} in the following:

$$\frac{f_c+f_{cu}}{2} \cdot t \cdot b = A_s \cdot f_s$$

we get $\frac{f_c + f_c \cdot \frac{x-t}{x}}{2} \cdot t \cdot b = A_s \cdot n \cdot f_c \cdot \frac{d-e-x}{x}$

and from this

$$x=\frac{n \cdot A_s (d-e)+\frac{t^2 . b}{2}}{t \cdot b+n \cdot A_s}$$

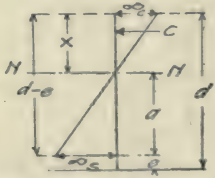
and since $x-y=\frac{t}{3} \cdot \frac{f_c+2 \cdot f_{cu}}{f_c+f_{cu}}$ substituting a value for f_{cu}.

$$y=x-\frac{t}{2}+\frac{t^2}{6(2x-d)}$$

Since $$M = T(d-e-x+y)$$
$$= A_s \,.\, f_s \ (d-e-x+y)$$
$$\therefore A_s = \frac{M}{f_s \ (d-e-x+y)}$$

and from $f_s = n \,.\, f_c \,.\, \dfrac{d-e-x}{x}$ $\quad f_c = f_s \,.\, \dfrac{x}{n\,(d-e-x)}$

Derivation of formulæ for use of T beams is obtained thus:—



$$\frac{D_c}{x} = \frac{D_s}{a}$$

$$\frac{f_c}{E_c} \,.\, x = \frac{f_c}{E_c}(a)$$

$$x \cdot \frac{f_s}{f_c} = a \cdot \frac{E_s}{E_c} \qquad \therefore xr = a.n$$

$$\frac{f_s}{f_c} = r \qquad \therefore x = \frac{a.n}{r}$$

$\dfrac{E_s}{E_c} = n$ $\qquad$ and since $T = C.$ $\qquad \dfrac{f_c \,.\, x}{2}.b = A_s \, f_s$

$$\therefore A_s = \frac{f_c \,.\, x \,.\, b}{2 \,.\, f_s} = \frac{b.x}{2r}$$

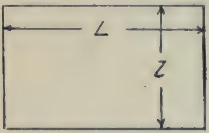
From formula (4) $$f_s = \frac{M}{\frac{b.n.(d-e)}{2r(r+n}\left[(d-e) - \frac{n(d-e)}{3(r+n}\right]}$$

$$\therefore d-e=\sqrt{\frac{2r(n+r)}{b.n.f_s\left[1-\frac{n}{3(r+n)}\right]}}\cdot\sqrt{M} \qquad (9)$$

$$\text{and} \quad A_s=\frac{n.b}{2r(r+n)}.(d-e) \qquad (10)$$

FLAT PLATES.

When designing flat plates either square or rectangular, use the following formulae:



$$M_L=\frac{WL}{8}\cdot\frac{l^4}{L^4+l^4}$$

$$M_l=\frac{W_l}{8}\cdot\frac{L^4}{L^4+l^4}$$

Representing $\frac{l^4}{L^4+l^4}$ by x and $\frac{L^4}{L^4+l^4}$ by y the following table will be found convenient:

$\frac{L}{l}$	y	x	$\frac{L}{l}$	y	x
1.0	0.500	0.500	1.6	0.867	0.133
1.1	0.592	0.408	1.7	0.892	0.108
1.2	0.675	0.325	1.8	0.912	0.088
1.3	0.740	0.260	1.9	0.929	0.071
1.4	0.798	0.202	2.0	0.941	0.059
1.5	0.835	0.165			

VERTICAL SHEAR IN SLABS.

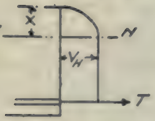
The shear is represented by V, area of steel by A_s area of concrete by A_c then stress in the concrete $=$

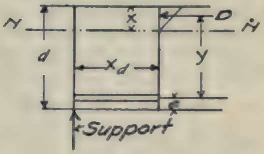
$$\frac{V}{A_c+n.A_s} \quad n=\frac{E_s}{E_c} \quad \text{and stress in steel} = \frac{V}{A_s+\frac{A_c}{n}}$$

HORIZONTAL SHEAR IN SLABS.

$$D.y = V.x_d$$

$$\therefore D = \frac{V}{d - e - \frac{x}{3}}$$





Substituting for $y = d - e - \frac{x}{3}$

then representing width of beam by

$$V_H = \frac{V}{b\left(d - e - \frac{x}{3}\right)} \qquad (a)$$

in order that the adhesion between the concrete and the steel is equal to the shear

$$V_s = \frac{V}{U\left(d - e - \frac{x}{(3)}\right)} \qquad (b)$$

when U is equal to the total perimeter of the steel in b inches of width of slab.

In beams use:

$$V_H = \frac{V}{b_1(d - e - x + y)} \qquad (c)$$

$$V_s = \frac{V}{U(d - e - x + y)} = V_H = \frac{b_1}{U} \qquad (d)$$

If the neutral axis falls within the slab formulae and can be used by substituting the value $\frac{\text{Span}}{3}$ in place of $b = 12$ in. If the neutral axis passes through the bottom of the slab, use b_1 instead of b. In most cases the figured shear will exceed the safe shear on the concrete (65 lb. per sq. in.)

If the cross-section of a side of a U is a, then the U will resist a shear equal to $2.a.$ 10,000 lb.

Formula (c) gives the unit horizontal shear in the concrete and generally exceeds the safe shearing stress of 65 lb. per sq. in. By bending up some of the bars at a distance o from point of support some more of the shear can be taken up. By using $o = \frac{(V max - V_o)\text{Clear span}}{\text{Total weight on the beam}}$ the point of bending up the bars is determined.

In bending up bars the adhesion of the remaining straight bars in the bottom of the beam must be investigated. Use formula (d) for this.

In order to facilitate computations in estimating, the following table has been prepared, which gives values of K for various total loads per foot of beam and different effective depths. The table is figured for twisted steel or patented bars using 20,000 lb. per sq. in. on the steel. The moment used was $\frac{Wl}{10}$ assuming continuous action of the beams. For other moments and values of fiber stress in steel use

$$\frac{Wl}{x} = \frac{(\text{total load in lb. per ft.})\quad(12'')\quad(\text{Span in feet})^2}{\left(\begin{matrix}\text{effective depth}\\ \text{in inches}\end{matrix}\right)\left(\begin{matrix}\text{Working value of steel}\\ \text{in lb. per sq. in.}\end{matrix}\right)(x)}$$

when $x = 8$; 9 or 10; $Wl = wl^2$ Tables on pages 64, 65 and 66.

To determine the compression, take the area of steel required and multiply same by 20,000 lb. or other fiber stress. This gives the total compression. Multiply the clear span divided by 3 (if this value does not exceed the spacing of beams) by the thickness of your slab, or distance to the neutral axis as it passes within the slab. This gives the amount of compression the concrete will take. If this is less than the total compression, provide steel at 10,000 lb. per sq. in. to take the remainder.

BENDING MOMENTS, DEFLECTIONS AND SHEARS FOR BEAMS OF UNIFORM SECTION—(*Cambria Steel Co.*)

W=Total load, in lb., uniformly distributed, including the weight of beam.

W_1=Total superimposed or live load, in lb., uniformly distributed.

W_2=Total weight of beam or dead load, in lb., uniformly distributed.

P, P_1, P_2, P_3=Loads, in lb., concentrated at any points.

M=Total bending moment, in inch-lb.

M_{w1}, M_p=Bending moments, in inch-lb., due to weights W_1 and P respectively.

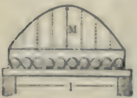
I=Moment of Inertia, in inches^4.

l=Length of span, in inches.

E=Modulus of elasticity, in lb. per square inch=29,000,000 for steel.

W_s =Total safe load, in lb., uniformly distributed, including weight of beam=Total safe load of tables.

The ordinates in diagrams give the bending moments for corresponding points on beam. For superimposed load only, make W_2 in formulæ equal to zero.



(1) Beam Supported at Both Ends and Uniformly Loaded.

Diagram for total load:—

Draw parabola having $M=\frac{Wl}{8}$

Safe superimposed load, in lb., uniformly distributed, $W'_s=W_s-W_2$.

Maximum bending moment at middle of beam=

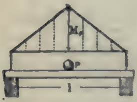
$$M=\frac{Wl}{8}=\frac{(W_1+W_2)\,l}{8}.$$

Maximum shear at points of support=

$$\frac{W}{2}=\frac{W_1+W_2}{2}.$$

Maximum deflection=

$$\frac{5}{384}\,\frac{Wl_3}{EI}=\frac{5}{384}\,\frac{(W_1+W_2)\,l^3}{EI}.$$



(2) Beam Supported at Both Ends with load Concentrated at the Middle.

Diagram for superimposed load:—

Draw triangle having $M_p=\frac{Pl}{4}$

Diagram for dead load similar to case (1).

Safe superimposed load, in lb., concentrated,

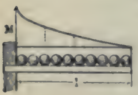
$$P_s=\frac{W_s-W_2}{2}.$$

Maximum bending moment at middle of beam=

$$M=\frac{Pl}{4}+\frac{W_2 l}{8}.$$

Maximum shear at points of support$=\frac{P+W_2}{2}.$

Maximum deflection$=\frac{Pl^3}{48EI}+\frac{5}{384}\,\frac{W_2\,l^3}{EI}.$



(3) Beam Fixed at One End, Unsupported at the Other and Uniformly Loaded.

Diagram for total load:—

Draw parabola having $M=\frac{Wl}{2}$

Safe superimposed load, in lb., uniformly distributed,

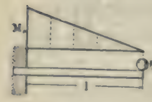
$$W'_s=\frac{W_s}{4}-W_2.$$

Maximum bending moment at point of support=

$$\frac{Wl}{2}=\frac{(W_1+W_2)\,l}{2}.$$

Maximum shear at point of support$= W = W_1 + W_2$.

Maximum deflection $= \frac{Wl^3}{8EI} = \frac{(W_1 + W_2)\,l^3}{8EI}$.



(4) Beam Fixed at One End, and Unsupported at the Other, with Load Concentrated at the Free End.

Diagram for superimposed load:—
Draw triangle having $M_p = Pl$.
Diagram for dead load similar to case (3).
Safe superimposed load, in lb., concentrated,

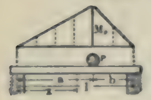
$$P_s = \frac{W_s - 4\,W_2}{8}$$

Maximum bending moment at point of support=

$$Pl + \frac{W_2 l}{2}$$

Maximum shear at point of support$= P + W_2$.

Maximum deflection $= \frac{Pl_3}{3EI}\,\frac{+\,W_2\,l^3}{8EI}$



(5) Beam Supported at Both Ends with Load Concentrated at any Point.

Diagram for superimposed load:—
Draw triangle having $M_p = \frac{Pab}{l}$.

Diagram for dead load similar to case (1).
Safe superimposed load, in lb., concentrated,

$$P_s = \frac{W_s\,l^2 - 4a\ W_2\ (l-a)}{8ab}.$$

Maximum bending moment under load=

$$\frac{a\ (2\ Pb + W_2 l - W_2 a).}{2l}$$

Maximum shear at sup. near $a = \frac{Pb}{l} + \frac{W_2}{2}$

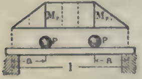
Maximum shear at sup. near $b = \frac{Pa}{l} + \frac{W_2}{2}$.

Deflection at distance x from left support=

$$\frac{1}{3lEI}\left[\frac{2al-a_2}{3}\right]^{\frac{3}{2}}$$

$$\left[Pb+\frac{W_2}{8}\left(2l-\sqrt{\frac{2al-a^2}{3}}-\frac{3l^3}{2al-a^2}\right)\right]$$

$x=\sqrt{\frac{2al-a^2}{3}}=$ Distance, from left support, of point of maximum deflection for superimposed load.



(6) Beam Supported at Both Ends with Two Symmetrical Loads.

Diagram for superimposed load:—
Draw trapezoid having $M_p = Pa$.

Diagram for dead load similar to case (1).
Safe superimposed load, in lb., concentrated, each

$$P_s=\frac{W_s\,l-W_2l.}{8a}$$

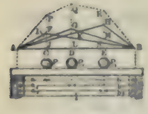
Maximum bending moment at center of beam=

$$Pa+\frac{W_2l}{8}.$$

Maximum shear at points of support=

$$\frac{2P+W_2}{2}.$$

Maximum deflection$=\frac{Pa}{24EI}\left(3l^2-4a^2\right)+\frac{5}{384}\frac{W_2l^3}{EI}.$



(7) Beam Supported at Both Ends with Loads Concentrated at Various Points.

The total bending moment at any point produced by all the weights is equal to the sum of the moments at that point produced by each of the weights separately.

Diagram for dead load similar to case (1).

The maximum bending moment occurs at the point where the vertical shear equals zero and will be at one of the loads P, P_1, or P_2 depending upon their amounts and spacing if W_2 is neglected.

Let R=Reaction at left support.

Bending moment at P=

$$M_p = Ra - \frac{W_2 a^2}{2l}.$$

Bending moment at P_1=

$$M_{p\,1} = Ra_1 - \left[\frac{W_2 a_1^2}{2l} + P\ (a_1 - a)\right].$$

Bending moment at $P_2 = M_{p2} = Ra_2 -$

$$\left[\frac{W_2 a_2^2}{2l} + P_1(a_2 - a_1) + P(a_2 - a)\right].$$

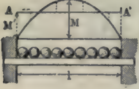
Shear or reaction at left support=

$$\frac{P_2 b_2 + P_1 b_1 + Pb}{l} + \frac{W_2}{2}.$$

Shear or reaction at right support=

$$\frac{P_2 a_2 + P_1 a_1 + Pa}{l} + \frac{W_2}{2}.$$

Diagram for superimposed load:—Draw as in case (5) the ordinates FC, GD and HE representing the bending moments due to loads P, P_1 and P_2 respectively. Produce FC to P, making $PC=FC+IC+JC$; GD to Q, making $QD=GD+KD+LD$; and HE to R, making $RE=HE+ME+NE$. Join the points A, P, Q, R and B, then the ordinates between $A\ B$ and polygon $A\ P\ Q\ R\ B$ will represent the bending moments for corresponding points on beam.



(8) Beam Fixed at Both Ends and Uniformly Loaded.

Diagram for Total Load:—Draw parabola having $M=\frac{Wl}{8}$. Also AA' parallel to base and at a distance $M'=\frac{Wl}{12}$. The Vertical distances between the parabola and line AA' are the moments for corresponding points on beam.

Safe superimposed load, in lb., uniformly distributed, $W'_s=\frac{3}{2}W_s-W_2$.

Distance of points of contra-flexure from supports =.2113l.

Maximum bending moment at points of support=

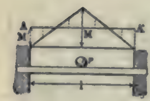
$$\frac{Wl}{12}=\frac{(W_1+W_2)l}{12}.$$

Bending moment at middle of beam=

$$\frac{Wl}{24}=\frac{(W_1+W_2)l}{24}.$$

Maximum shear at points of support$=\frac{W_1+W_2}{2}$.

Maximum deflection$=\frac{Wl^3}{384EI}=\frac{(W_1 W_2)l^3}{384EI}$



(9) Beam Fixed at Both Ends With Load Concentrated at the Middle.

Diagram for superimposed load:—Draw triangle having $M=\frac{Pl}{4}$. Also $A\,A'$ parallel to base and at a distance $M'=\frac{Pl}{8}$. The vertical distances between the triangle and line $A\,A'$ are the moments for corresponding points on beam.

Diagram for dead load similar to case (8).

Safe superimposed load, in lb., concentrated, $P_s = W_s - \frac{2}{3} W_2$.

Distance of points of contra-flexure from supports $= \frac{1}{4} l$.

Maximum bending moment at points of supports $=$

$$\frac{Pl}{8} + \frac{W_2 l}{12}.$$

Bending moment at middle of beam $= \frac{Pl}{8} + \frac{W_2 l}{24}$.

Maximum shear at points of support $= \frac{P + W_2}{2}$.

Maximum deflection $= \frac{Pl^3}{192EI} + \frac{W_2 l^3}{384EI}$.

VALUES OF K FOR DIFFERENT TOTAL LOADS PER FOOT AND EFFECTIVE DEPTHS.

Effective depth	Total Load per Foot 1500 to 2500 Values of K										
	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500
10..........	.0090	.0096	.0102	.0108	.0114	.0120	.0126	.0132	.0138	.0144	.0150
11..........	.0082	.0087	.0093	.0098	.0104	.0110	.0115	.0120	.0125	.0130	.0136
12..........	.0075	.0080	.0085	.0090	.0095	.0010	.0105	.0110	.0115	.0120	.0125
13..........	.0069	.0074	.0679	.0083	.0088	.0093	.0097	.0102	.0106	.0110	.0115
14..........	.0064	.0069	.0073	.0077	.0082	.0086	.0090	.0094	.0099	.0103	.0107
15..........	.0060	.0054	.0068	.0072	.0076	.0080	.0084	.0088	.0092	.0096	.0100
16..........	.0056	.0060	.0064	.0068	.0072	.0075	.0079	.0083	.0086	.0090	.0094
17..........	.0053	.0057	.0060	.0064	.0067	.0071	.0074	.0078	.0081	.0085	.0089
18..........	.0050	.0054	.0057	.0060	.0064	.0067	.0070	.0074	.0077	.0080	.0084
19	.0047	.0051	.0054	.0057	.0060	.0063	.0066	.0070	.0073	.0076	.0079
20..........	.0045	.0048	.0051	.0054	.0057	.0060	.0063	.0066	.0069	.0072	.0075
21..........	.0043	.0046	.0049	.0052	.0055	.0057	.0060	.0063	.0066	.0069	.0072
22..........	.0041	.0044	.0047	.0049	.0052	.0055	.0057	.0060	.0063	.0066	.0068
23..........	.0039	.0042	.0045	.0047	.0050	.0052	.0055	.0058	.0060	.0063	.0065
24..........	.0038	.0040	.0043	.0045	.0048	.0050	0053	.0055	.0058	.0060	.0063
25..........	.0036	.0038	.0041	.0043	.0046	.0048	.0051	.0053	0055	.0058	.0060
26..........	.0035	.0037	.0039	.0042	.0044	.0046	.0049	.0051	.0053	.0056	.0058
27..........	.0033	.0036	.0038	.0040	.0042	.0045	.0047	.0049	.0051	.0054	.0056
28..........	.0032	.0034	.0037	.0039	.0041	.0043	.0045	.0047	.0050	.0052	.0054
29..........	.0031	.0033	.0035	.0037	.0040	.0042	.0044	.0046	.0048	.0050	.0052
30..........	.0030	.0032	.0034	.0036	.0038	.0040	.0042	.0044	.0046	.0048	.0050

VALUES OF "K" FOR DIFFERENT TOTAL LOADS PER FOOT AND EFFECTIVE DEPTHS. STRESS ON STEEL 20,000 POUNDS.

For $\frac{Wl}{10}$ then $\frac{(\text{Total load per ft.}) \times (1.2)}{(\text{Effective depth}) \times (20000)} = K$ $\quad A_s = Kx \quad l^2$

800 to 1400

Effective Depth	800	400	500	600	700	800	900	1000	1100	1200	1300	1400
10....	.0018	.0024	.0030	.0036	.0042	.0048	.0054	.0060	.0066	.0072	.0078	.0084
11....	.00163	.0022	.0027	.0033	.0038	.0044	.0049	.0055	.0060	.0065	.0071	.0076
12....	.0015	.0020	.0025	.0030	.0035	.0040	.0045	.0050	.0055	.0060	.0065	.0070
13....	.00138	.0019	.0023	.0028	.0032	.0037	.0042	.0046	.0051	.0056	.0060	.0065
14....	.00128	.0017	.0022	.0026	.0030	.0034	.0039	.0043	.0047	.0052	.0056	.0060
15....	.0012	.0016	.0020	.0024	.0028	.0032	.0036	.0010	.0044	.0048	.0052	.0056
16....	.00112	.0015	.0019	.0023	.0026	.0030	.0034	.0038	.0041	.0045	.0049	.0053
17....	.00106	.0014	.0018	.0022	.0025	.0029	.0032	.0036	.0039	.0043	.0046	.0049
18....	.00100	.00133	.0017	.0020	.0024	.0027	.0030	.0034	.0037	.0040	.0043	.0047
19....	.00095	.0013	.0016	.0019	.0022	.0026	.0029	.0032	.0035	.0038	.0041	.0044
20....	.00090	.0012	.0015	.0018	.0021	.0024	.0027	.0030	.0033	.0036	.0039	.0042
21....	.00086	.00115	.00143	.0017	.0020	.0023	.0026	.0029	.0032	.0035	.0038	.0040
22....	.00082	.0011	.0014	.00164	.0019	.0022	.0025	.0028	.0030	.0033	.0036	.0038

23....	.00078	.00105	.0013	.00156	.00183	.0021	.0024	.0026	.0029	.0031	.0034	.0037
24....	.00075	.00010	.0013	.0015	.0018	.0020	.0023	.0025	.0028	.0030	.0033	.0035
25....	.00072	.00096	.0012	.00145	.0017	.00195	.0022	.0024	.0027	.0029	.0031	.0034
26....	.00069	.00092	.0012	.0014	.00161	.00184	.0021	.0023	.0026	.0028	.0030	.0032
27....	.00067	.00089	.0011	.00133	.0016	.0018	.0020	.0022	.0025	.0027	.0029	.0031
28....	.00064	.00085	.0011	.0013	.0015	.0017	.0019	.0022	.0024	.0026	.0028	.0030
29....	.00062	.00083	.0010	.00125	.0015	.0017	.0019	.0021	.0023	.0025	.0027	.0029
30....	.00060	.00080	.00100	.00120	.0014	.0016	.0018	.0020	.0022	.0024	.0026	.0028

For beams merely supported use $\frac{Wl}{8}$ multiply "K" by (1.25). **Note:** W = wl

For beams partly continuous use $\frac{Wl}{9}$ multiply "K" by (1.11).

The steel required is obtained by multiplying "K" by the clear span in feet squared. For very accurate work "K" should always be carried to five decimal places. Investigate for compression, negative moment, horizontal and vertical shear. See general notes on placing steel.

To determine for negative moment find your moment at the support and see whether you have enough steel at the top to take it.

To determine vertical shear, take the cross section of the beam from top of slab to center of steel. Deduct this from the total shear and the remainder of the shear will determine how many straight bars at 10,000 lb. per sq. in. you must have at the bottom of the beam at supports.

To determine the horizontal shear, figure what your concrete takes per effective depth; then place U's in each effective depth to take the remaining shear.

In the following examples from the booklet issued by the Ransome Machinery Co., (which have been checked) are given formulae used in the Ransome System.

"If the Ransome system is used, the following formulas will facilitate the calculations necessary to properly design concrete steel structures. In the examples the safe strength of the steel is taken from the following table which gives a factor of safety of four. For important work it is advisable to consult a competent concrete engineer.

WALL AND PIER FOOTINGS.

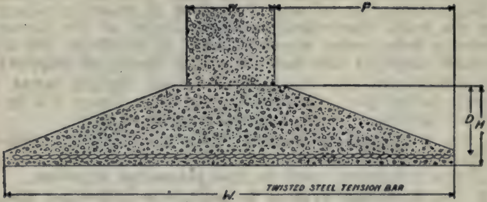
Plates I and II illustrate the general form and arrangement of tension bars in our standard wall and pier footings.

FORMULA FOR WALL FOOTINGS.

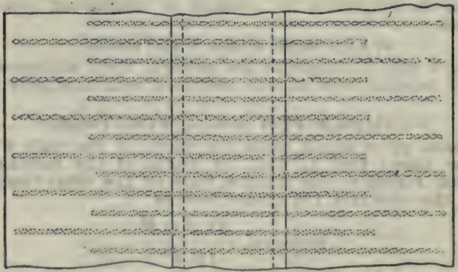
We have given in all cases the width of the wall W, the load per linear foot L, and the width of the footing Wl. The total stress in the tension bars or the total compression in the concrete per linear foot is

$$\text{Stress} = \frac{2 \times L \times P}{7 \times D}$$

in which L equals the total load in tons, P equals the projection in inches and D equals the distance in inches from the top of the footing to the center of the bars. We have two unknown quantities, Stress and D. It is therefore necessary to impose another condition, and it is that when the safe compressive strength of the concrete equals 35 tons per sq. ft. there shall be 16 sq. in. of concrete in the area above, the bars for each ton stress or $16 \times \text{stress} = 12 \times D$ from which $\text{stress} = \frac{3}{4} D$. This condition is necessary in order that the concrete shall not be strained

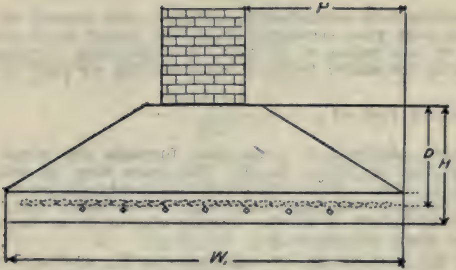


SECTION THROUGH WALL FOOTING

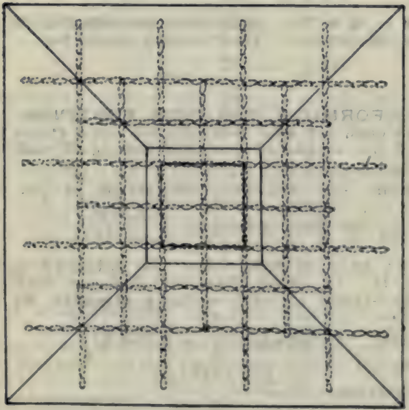


PLAN OF WALL FOOTING

Plate I.



ELEVATION OF PIER FOOTING



PLAN OF PIER FOOTING.

Plate II.

beyond its safe compressive strength and should be modified to suit this strength when the latter does not conform to the value of 35 tons. Substituting this value of stress in the above formula and reducing we have D equals

the square root of $$\frac{8 \times L \times P}{21}$$

Having obtained D from this formula the total stress in the bars in tons $= \frac{3}{4}\ D$. The bars may be placed as shown in plan. The size of the bars should be so taken that the bars will not be spaced more than 12 in. apart. The total height H of the footing should be at least 3 in. greater than the depth D.

Let $W = 2$ ft., load $= 20$ tons per lin. ft., and safe bearing power of soil $= 2$ tons. Then $W_1 = 10$ ft. and $P = 4$ ft. D equals the square root of

$$\frac{8 \times 20 \times 48 \text{ in.}}{21} = 19 \text{ inches}$$

And stress = ¾ x 19 = 14.25 tons, requiring ¾ in. square bars 4¾ in. on centers. Their length would be

$$W_1 - \frac{P}{2} = 8 \text{ ft.}$$

II. FORMULA FOR PIER FOOTINGS.

As in the case for wall footings we have given the dimensions of the supported pier and footing W and W_1 and the total load carried L.

Our formula for obtaining the stress in the tension bars running in each direction is $\frac{L \times P}{3 \times D}$

in which we have as before the two unknown quantities stress and D. In order that the concrete may not be compressed beyond its safe working strength we impose

the condition $$4 \times \text{Stress} = \frac{D}{2} \times (W + 6)$$

from which stress $$= \frac{D \times (W + 6)}{8}$$

Substituting this value of stress in the above formula and reducing we have D equals the square root of

$$\frac{8\times L\times P}{3(W+6)}$$

Having obtained D by this formula, the total stress in tons equals

$$\frac{W+6}{8}\times D$$

from which the size and number of bars running in each direction can be computed. These bars may be made in two lengths as shown on plan, Plate II, the shorter length being equal to $W+P$. The total height H should not be less than $D+4$ in.

Let $W=16$ in. Load $=80$ tons. Safe bearing power of soil $=2$ tons. The required area of base of footing is 40 sq. ft., and the width W_1 equals the square root of 40 $=6$ ft. 4 in. or 76 in. and $P=30$ in.

D equals the square root of $\dfrac{8\times 80\times 30}{3\times 22}=17$ in.

The total stress would therefore be

$$\frac{22}{8}\times 17=47 \text{ tons}$$

requiring 9-¾ in. bars or 19-½ in. bars in each direction.

These bars should be spaced equally over W_1-D

The total height H would be $D+4$ in.

FORMULAS FOR RANSOME FLOORS.

1st. Flat Floors: Our general formula for calculating the maximum tensile stress or the maximum compressive stress in any beam supported at both ends and uniformly loaded is

$$\text{Stress}=\frac{L\times S}{7\times D}$$

in which L equals total live and dead load supported, in tons; S equals span, in inches; and D equals distance from top of beam to center of bar, in inches.

When the beam is not uniformly loaded the formula for maximum stress is

$$\text{Stress}=\frac{B\,M\times 8}{7\times D}$$

in which BM equals maximum bending moment, in inch tons.

In order that the compressive stress per linear foot resulting from a chosen value for D shall not exceed the safe compressive strength of the concrete there must be 16 sq. in. of concrete above the bars for each ton stress or 16 x stress equals 12 x D; from which stress $= \frac{3}{4} D$. Substituting this value of stress in the above formula and reducing, we have $D =$ square root of

$$\frac{4 \times L \times S}{21}$$

Having obtained D, the total stress in tons $= \frac{3}{4} D$. The total thickness of the floor must be ½ in. greater than D if ¼ in. bars are used and ¾ in. greater if ½ in. bars are used.

Assume a flat floor of 10 ft. span loaded with 100 lb. per sq. ft.

It will be necessary to assume the dead weight of the floor guided by experience. We will suppose it to be 60 lb., making the total load 160 lb. per sq. ft. The total load L on a strip of floor 1 ft. wide would be

$$\frac{10 \times 160}{2000} = .8 \text{ ton}$$

and D would equal the square root of

$$\frac{4 \times .8 \times 10 \times 12}{21} = 4.28 \text{ inches.}$$

The total stress in the bars would equal ¾ x 4.28 = 3.21 tons, requiring ¼ in. bars 2¼ in. on centers. The total thickness would equal 4¾ in.

Ribbed Floors: In calculating the dimensions and tension bar for ribbed floors we use the general formula

$$\text{Stress} = \frac{L \times S}{7 \times D}$$

In order that the concrete in the top member of the floor may not be strained beyond its safe compressive strength, we make the condition that the upper third of the beam including the flat slab connecting the beams shall contain at least 5 sq. in. of concrete for each ton stress given by the formula.

Assume a ribbed floor of 20 ft. span loaded with 150 lb. per sq. ft., to find the dimensions of floor and size of tension bar.

From experience we would assume the weight of the floor to be about 50 lb. per sq. ft., making the total load per sq. ft. equal to 200 lb. We would also have to establish the spacing of the beams, which in most cases would preferably be from 36 in. to 48 in. between centers.

For 36 in. between centers the total load on each beam

$$L=\frac{20\times36\times200}{12\times2000}=6 \text{ tons}$$

and the total stress $\dfrac{6\times20\times12}{7\times D}=\dfrac{206}{D}$.

If we use a 1 in. bar having a safe tensile strength of 10 tons, the depth D would equal 20.6 in. The minimum thickness for the slab to give the required compressive strength would be $\dfrac{5\times10}{36}=1.4$ in.

an amount less than it would be advisable to use, practical considerations suggesting a minimum thickness of 2 or 2½ in.

The slab should be figured as a flat floor spanning from beam to beam.

The width of beam W and total height H depend upon the size of the bar and are given in table below.

Size of Bar	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	1¾ in.	2 in.
	in.	in.	in.	in.	in.	in.	in.
H	D+¾	D+1⅛	D+½	D+1⅞	D+2¼	D+2⅝	D+3
W	1½	2¼	3	3¾	4½	5¼	6

If, instead of a 1 in. bar we should use a 1¼ in. bar having a safe tensile strength of 15.625 tons, the least depth D would be 13.2 in., the minimum thickness T would be

$$\frac{15.625\times5}{36.}=2.17 \text{ in.}$$

and the other dimensions would be obtained from the 1¼ in. bar column in the table.

Where the length of span warrants it, one or more stiffening ribs should be formed, at right angles to the resting on top of the beam tension bar. The purpose of these ribs is to stiffen the beams laterally, and in case of heavy concentrated loading to distribute the stresses resulting therefrom over beams adjacent to the load. The size of the tension bar will depend upon the number of beams desired to act as a unit, the stiffening rib being treated as a beam loaded at the points of intersection with the floor beams.

The stress in a beam supported at one end is four times the stress in a beam of same span and loading supported at both ends. Hence the formula for cantilever beams uniformly loaded* is

$$\text{Stress} = \frac{4 \times L \times P}{7 \times D}$$

where *P* equals projection, in inches.

The tension bar is placed in the top of the beam and the portion below the bar must contain at least 16 sq. in. of concrete for each ton stress.

Stirrups or U-bars placed as indicated by Fig. 1, Plate III, provide resistance to shearing stresses.

In addition to those in the beams at each intersection of beams and stiffening ribs place a U-bar of the same size as those in the beams. Also where a beam or girder is supported by a girder, place a U-bar at the intersection passing under the tension bars of the supporting girder.

Instead of U-bars a continuous coil as shown by Fig. 2, may be used. All bends for U-bars and coils should be made with the longest possible radius to avoid weakening the metal.

Another form of reinforcement against shear is shown by Fig. 3 consisting of a number (in this case 4) of small tension bars in place of one large one, the ends of which are bent up, as shown, at varying distances from the point of support. In placing, the bars should be held apart by means of small separators sufficiently to allow the mortar to work well in between them.

Any desired combination of the above forms may be used."

RETAINING WALLS.

The following excerpt is made from the booklet of the Concrete Steel Retaining Wall Co. on the Bone System of retaining wall construction:

"It is easy to design a reinforced concrete wall of the same stability of any example of solid wall that may be selected. The heel can be made of sufficient length, so that the earth on the heel, together with the wall, will be just as heavy as the example. The concrete steel beams can be made strong enough to resist the same force which will not overturn the wall as a whole. But a reinforced wall so designed does not get the full benefit of the advantages which it has over a gravity wall. So it is better to use methods of design which are somewhat different from those commonly used for retaining walls. The formulas herein given determine the proper dimensions which a wall should have to best resist failure, considering the probable earth thrust and the bearing power of the foundation bed on which the wall is to be built.

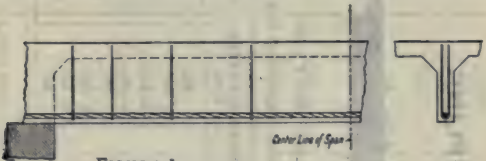


FIGURE 1

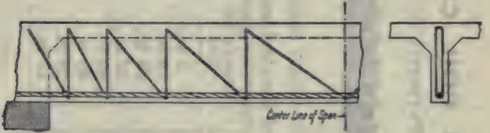


FIGURE 2

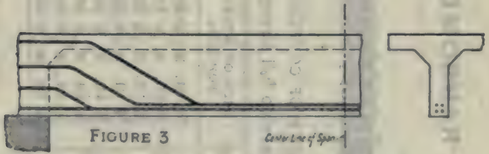
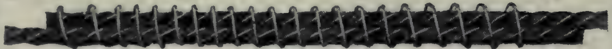


FIGURE 3

PLATE III

RANSOME'S COIL COUPLING

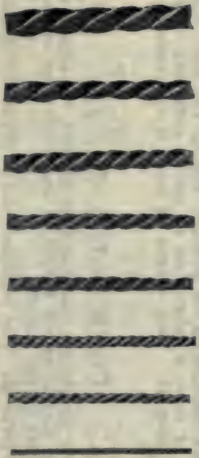
(PATENTED)



LENGTH OF COUPLING EXPANDED EQUALS LENGTH OF LAP

This Coil will develop full strength of the steel bar without splitting the concrete.

SIZE OF BAR TO BE COUPLED	SIZE OF STEEL FOR COIL	LENGTH OF COIL	INSIDE DIAMETER OF COIL	TOTAL NO. OF TURNS
¼ in. x ¼ in.	⅛ in. x ¼ in.	8 in.	1 in.	7
½ in. x ½ in.	⅛ in. x ¼ in.	16 in.	1¾ in.	14
¾ in. x ¾ in.	⅛ in. x ½ in.	24 in.	2½ in.	21
1 in. x 1 in.	⅛ in. x ½ in.	32 in.	3¼ in.	28
1¼ in. x 1¼ in,	¼ in. x ½ in.	40 in.	4 in,	35
1½ in. x 1½ in.	¼ in. x ½ in.	48 in.	4¾ in.	42
1¾ in. x 1¾ in.	¼ in. x ½ in.	56 in.	5½ in.	49
2 in. x 2 in.	¼ in. x ½ in.	64 in.	6 in.	56



SIZE OF BAR	WEIGHT PER FOOT	ELASTIC LIMIT	ULTIMATE STRENGTH
1¼ in. square	5.312	55450	83150
in. square.	3 400	55760	84275
⅞ in. square	2.603	56150	84730
¾ in. square	1.913	56720	85240
⅝ in. square	1 328	57890	85820
½ in. square	.850	60120	86350
⅜ in. square	478	61800	86600
¼ in. square	.213	62350	86700

Earth Thrust: Many complex theories have been devised to calculate the earth thrust, but the assumptions on which these theories are based are so variable and hard to determine with accuracy that they give far from practical results. However, they are the best at hand, and serve to obtain results much better than by direct assumptions. Rankine's is one of the standard formulas, and can be expressed as

$$T=\frac{w\ H}{2}\left(\frac{1-sin\,\phi}{1+sin\,\phi}\right)$$

Where T equals earth thrust, H equals height of wall, w equals weight per cu. ft. of backing x H and ϕ equals the angle of repose. What few experiments have been made to verify these formulas indicate that the actual earth thrust under a backing of certain weight and angle of repose is about one-half of the calculated value. The angle of repose is taken as the smallest angle at which the given earth will repose, and is seldom less than 1½ on 1. This will give the maximum normal earth thrust. However, in actual cases the earth will probably repose at a steeper angle, due to the cohesion in the earth, and the earth thrust will be less. This maximum normal thrust can now be multiplied by a factor of safety to get the ultimate value. We use a factor of safety of 3 or 4 for external stresses and 6 to 8 for internal stresses. These factors are large, the factors for gravity walls seldom being taken over 3. With a more economical structure we can afford to use a larger factor of safety.

A reinforced wall may fail (1) internally, or (2) externally. It may fail externally (a) by overturning, or (b) by sliding forward on the base.

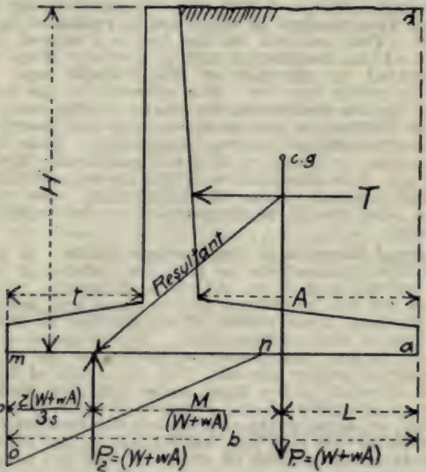
Sliding: To produce sufficient friction between the base and the foundation to prevent sliding the heel must be made of such a length as to get a sufficient weight of earth upon it. This length of heel is expressed by the formula

$$T=f\,(W+wA) \text{ or } A=\frac{T-f\,W}{f\,w}$$

Where f equals the coefficient of friction, W equals weight of wall and w equals weight of one cubic foot of backing, multiplied by the height.

Overturning: The resultant earth thrust is assumed to act at one-third of the height (H) of the wall from the base. The overturning moment then is

$$M = T\frac{H}{3}$$



To obtain the proper length of the base to resist this overturning moment, and to prevent crushing or settlement of the earth under the toe,

$$b = \frac{2(W+wA)}{3s} + \frac{M}{(W+wA)} + L$$

where L equals distance of the resultant center of gravity of the wall and earth on the heel, from the end of the heel, and s equals the bearing power of the foundation bed. If the foundation bed is liable to serious settlement, the position of $P2$ under the maximum normal earth thrust is found, and the toe extended until $P2$ cuts the base in the middle. This will keep the unit pressure the same all along the base and the settlement uniform.

Internal Stresses: To prevent internal failure the concrete steel beams are figured by the usual methods of concrete steel design. In the inverted T or L type of wall the trunk, the heel and the toe are simply cantilever beams. The moment on the trunk is produced by the earth thrust. The moment on the toe is produced by the reaction of the foundation acting upward. This reaction is represented by the part of the triangle *mno* (see Fig.) directly under the toe. The moment in the heel is produced by the weight of the earth on the heel, the force due to friction in the plane *aa′* and the reaction, if any, on the foundation, acting negatively. This reaction is represented by the part of the triangle *mno* directly under the heel. The distribution of the stresses in the heel and toe vary greatly under different loads. So the stresses in the base should be considered for the various possible loadings.

Internal Stresses of Counterfort Walls: In counterfort walls the counterforts or ribs are reinforced sufficiently to carry the load of an entire panel length. The stresses caused by the pressures in the face and base must be carried from their points of application to the counterforts, by a slab construction. These slabs act as continuous beams, and must be reinforced on each side of the slab at proper places. The variation of the position of the stresses in the base under different loads necessitates an analysis of the stresses for all of the possible loading. In some parts of the slab the tension may sometimes be on one side and sometimes on the other, requiring rods on both sides of the slab, and the pressure may be concentrated on one part or it may be distributed. The action of continuity which occurs at the juncture of the face with the floor slab requires vertical rods in the back part of the face slab, continuing down along the top of the base. The positions of the shearing stresses under the various loads must be determined and resisted. A larger factor of safety should be allowed a counterfort wall than a T wall, in regard to internal stresses, because in a T wall the rods act strictly in series, and, being numerous, a defect or failure in one would be of little importance, while in a counterfort wall a defect in one member might endanger the wall for an entire panel length. Also, in the thin slabs that are used in counterfort walls a slight displacement in a rod makes considerable difference in the strength of the slab, while an equal displacement in a rod of a thicker beam as used in T walls would not make such a difference in its strength.

The decreased dead load obtained by slab construction does not give the advantage to retaining walls that it does to floors of buildings or bridges, because the weight of the beam itself, in the case of walls, is an aid to stability.

CONCRETE COLUMNS.

Concrete columns can be designed according to the following formula based on the assumption that the load is borne by the concrete and steel in a ratio depending on the relative moduli of elasticity. Let

c_1 = total unit compression upon the concrete and steel, (i. e., the total load divided by the combined area of concrete and steel) in lbs. per sq. in.

C = unit compression in concrete in lbs. per sq. in.

p = ratio of cross-section of steel to total cross-section of column.

$r = \frac{E_s}{E_c}$ ratio of moduli of elasticity.

Then

$$c^1 = C[(1-p)+rp]$$

$$pc_1 = \frac{c_1 - c}{c(r-1)}$$

WEIGHTS OF POROUS OR DENSE TERRA COTTA PARTITIONS. (Kidder).

In. in Thickness.	Lb. per Sq. Ft.
3	12 to 16
4	13 to 19
5	20 to 22
6	22 to 23
8	28 to 33

Note.—Plaster not included in the above. Will add about 10 lb. per sq. ft. for both sides.

CRUSHING HEIGHT OF BRICK AND STONE. (Kidder).

If we assume the weight of brick work to be 120 lb. per cu. ft., and that it would commence to crush under 100 lb. per sq. in., then a wall of uniform thickness would have to be 840 ft. high before the bottom courses would commence to crush from the weight of the brickwork above.

Average sandstones at 145 lb. per cu. ft. would require a column 5950 ft. high to crush the bottom stones; an average granite at 165 lb. per cu. ft. would require a column 10,470 ft. high. The Merchants' shot-tower at Baltimore is 246 ft. high, and its base sustains a pressure of six tons and a half (of 2,240 lb.) per sq. ft. The base of the granite pier of Saltash Bridge (by Brunel) of solid masonry to the height of 96 ft., and supporting the ends of two iron spans of 455 ft. each, sustains 9 tons and a half per sq. ft.

WEIGHTS PER SQ. FT. OF ROOF SURFACE. (Kidder).

Shingles, common, 2½ lb.; 18 in., 3 lb.

Slates, 3-16 in. thick, 7¼ lb.; ¼ in. thick, 9.6 lb.

Plain tiles or clay shingles, 11 to 14 lb.

Roman tiles, old style, 2 parts, 12 lb.; new style, 1 part, 8 lb.

Spanish tiles, old style, 2 parts, 19 lb.; new style, 1 part, 8 lb.

Improved Oriental tiles, 11 lb.

Ludowici tile, 8 lb.

(For tiles laid in mortar, add 10 lb. per sq. ft.)

Copper roofing, sheets, 1½ lb.; tiles, 1¾ lb.

Tin roofing, sheets or shingles, including 1 thickness of felt, 1 lb.

Corrugated iron, painted or galvanized, No. 26, 1 lb.; No. 24, 1.3 lb.; No. 22, 1.6 lb.; No. 20, 1.9 lb.; No. 18, 2.6 lb.; No. 16, 3.3 lb.

Standing seam steel roofing, 1 lb.

Five ply felt and gravel roof, 6 lb.

Four ply felt and gravel roof, 5½ lb.

Three ply ready roofing, (elaterite, ruberoid, asphalt, etc.), 0.6 to 1 lb.

Skylights with galvanized iron frame, ¾ in. glass, 4½ lb.; 5-16 in., 5 lb.; ⅜ in., 6 lb.

Sheathing, 1 in. thick, 3 lb. per sq. ft. for white pine, spruce or hemlock; 4 lb. for yellow or pitch pine.

Comparison of Building Laws.—(Kidder.)

Materials	Allowable Pressures in Tons per sq. ft.						
	Boston, 1897	Buffalo, 1897	New York, 1899	Chicago, 1893	St. Louis, 1897	Philadelphia, 1899	Denver, 1898
Granite, cut	60	....	72-172	......	......	......	40
Marble and limestone, cut	40	...	50-165				
Sandstone, hard, cut	30	....	28-115	......	......	......	12
Hard-burned brick in Portland cement	....	....	18	12½	15		
Hard-burned brick in natural cement	15	9	15	9	.....	15	9
Hard-burned brick in cement and lime	12	....	11½	......	11½	12	
Hard-burned brick in lime mortar	8	6	8	6½	11	8	8
Pressed brick in Portland cement	....	12					
Pressed brick in natural cement	....	9	....	......	......	......	12
Rubble stone in natural cement	....	5	8	......	......	10	12
Dimension stone in foundations	....	6	....	5-7	......	......	30
Portland cement concrete in foundations	....	4	15	......	......	15	10
Natural cement concrete in foundations	....	....	8	4	......	......	4

ALLOWABLE UNIT STRESSES AND LOADS IN ACCORDANCE WITH THE BUILDING LAWS OF VARIOUS CITIES—(*Cambria Steel Co.*)

(Revised to 1906)

ALLOWABLE UNIT STRESSES FOR STEEL AND IRON	Pounds per Square Inch			
	New York	Chicago	Phila.	Boston
COMPRESSION: Rolled Steel	16000	.....	14500	.....
Rolled steel	16000	.....	16250	.....
Cast "	16000	.....	.....	8000
Wrought iron	12000	.....	12500	.....
Cast " —in short blocks	16000	.....	17500	.....
Steel pins and rivets—bearing	20000	20000	.....	18000
Wrought iron pins and rivets—bearing	15000	15000	.....	15000
TENSION: Rolled steel	16000	15000	14500	15000
Rolled steel	16000	15000	16250	.....
Cast "	16000	.....	.....	.....
Wrought iron	12000	12000	12500	12000
Cast "	3000	.....	.....	.....
EXTREME FIBER STRESS—BENDING				
Rolled steel beams	16000	16000	.....	16000
" " pins, rivets and bolts	20000	22500	.....	22500
Riveted " beams—net flange section	14000	15000	.....	.....
Rolled wrought iron beams	12000	12000	.....	12000
" " " pins, rivets and bolts	15000	18000	.....	18000
Riveted " " beams—net flange section	12000	10000	.....	.....

Cast iron—compression side	16000	.....	.....	8000
" " tension "	3000	2500	3750	2500
Compression in flanges of built beams, steel	.....	.....	.....	12000
" " " " " " wrought iron	.....	.....	.....	10000
SHEAR: Steel web plates	9000	.....	8750	10000
Steel web plates	9000	.....	10000	10000
" shop rivets and pins	10000	10000	8750	10000
" " " " "	10000	10000	10000	10000
" field " " "	8000	10000	8750	10000
" " " " "	8000	10000	10000	10000
" " bolts	7000	.....	8750	10000
" " "	7000	.....	10000	10000
Wrought iron web plates	6000	.....	7500	9000
" " shop rivets and pins	7500	7500	7500	9000
" " field "	6000	7500	7500	9000
" " " bolts	5500	.....	7500	9000
Cast iron	3000	.....	.....	.....
COLUMNS: Mild steel	$15200-58\frac{L}{R}$	15000	$\frac{14500}{1+\frac{L^2}{13500R^2}}$	12000
Medium steel	"	15000	$\frac{16250}{1+\frac{L^2}{11000R^2}}$	12000
Wrought iron	$14000-80\frac{L}{R}$	12000	$\frac{12500}{1+\frac{L^2}{15000D^2}}$	10000
Cast iron	$11300-30\frac{L}{R}$	10000	$\frac{17500}{1+\frac{L^2}{400D^2}}$	See section 19 of Boston building laws.

STRENGTH OF WOODEN BEAMS. (Kidder).

To use the tables for beams that run less than nominal dimensions. In many localities floor joists as carried in stock are more or less scant of the nominal dimensions, and for such joists a reduction in the safe load must be made to correspond to the reduction in size. For beams ¼ in. scant in both dimensions the safe load may be obtained by multiplying the safe load as given in the table by the following factors:

For beams 1¾ in. × 5¾ in. by 1.6.
2¾ in. × 5¾ in. by 2.52.
1¾ in. × 6¾ in. by 1⅝.
2¾ in. × 6¾ in. by 2.55.
1¾ in. × 7¾ in. by 1.64.
2¾ in. × 7¾ in. by 2.58.
1¾ in. × 9¾ in. by 1.66.
2¾ in. × 9¾ in. by 2.61.
1¾ in. × 11¾ in. by 1.67.
2¾ in. × 11¾ in. by 2.63.
1¾ in. × 13¾ in. by 1.68.
2¾ in. × 13¾ in. by 2.65.
1¾ in. × 14¾ in. by 1.69.
2¾ in. × 14¾ in. by 2.66.
1¾ in. × 15¾ in. by 1.7.
2¾ in. × 15¾ in. by 2.66.

MAXIMUM LOAD PER SQ. IN. ON DIFFERENT KINDS OF MASONRY FROM BEARING PLATES. (Kidder).

Kind of Masonry.	Lb. per sq. in.
Granite	1,000
Sandstone (best grade)	700
Sandstone (soft)	400
Hard Stone Rubble	150 to 250
Extra-hard Brickwork in cement mortar	150 to 200
Hard Eastern Brickwork in lime mortar	120
Brickwork (common)	100
Portland Cement Concrete	200
Sand or Gravel	60

Allowable Unit Stresses and Loads in Accordance with the Building Laws of Various Cities—*Continued.*

(Revised to 1906)

Live Loads for Floors in Different Classes of Buildings, Exclusive of the Weight of Materials of Construction	Pounds per Square Foot			
	New York	Chicago	Philadelphia	Boston
Dwellings, apartment houses, hotels, tenement houses or lodging houses	60	50	70	50
Office buildings—first floor	150	100	100	100
" " above first floor	75	100	100	100
Schools or places of instruction	75	75	....	80
Stables or carriage houses	75	40 100	....	....
Buildings for public assembly	90	100	120	150
" " ordinary stores, light manufacturing and light storage	120	100	120	....
Stores for heavy materials, Warehouses and factories	150	....	150	250
Roofs—pitch less than 20°	50	25	30	25
" " more than 20°	30	25	30	25
Sidewalks	300	....	....	....
Public buildings, except schools	....	....	....	150

ALLOWABLE UNIT STRESSES FOR MASONRY AND BUILDING MATERIALS—Compression	Pounds per Square Inch			
	New York	Chicago	Philadelphia	Boston
Concrete, Portland cement, 1; sand, 2; stone, 4	230	55	208	....
" " " 1; " 2; " 5	208	55	208	....
" Rosendale or equal cement, 1; sand, 2; stone, 4	125	55	208	....
" " " " 1; " 2; " 5	111	55	208	....
Rubble stonework, Portland cement mortar	140	....	139	....
" " Rosendale " "	111	....	139	....
" " lime and " "	97	....	111	....
" " lime mortar	70	....	69½	....
Brickwork in Portland cement mortar; cement, 1; sand, 3	250	....	208	....
" in Rosendale, or equal, cement mortar; cement, 1; sand, 3	208	....	208	....
Brickwork in lime and cement mortar; cement, 1; lime, 1; sand, 6	160	....	167	....
Brickwork in lime mortar; lime, 1; sand, 4	111	....	111	....
Dimension stones in cement mortar	.....	70	....	....
" " " " dressed beds	.....	97	....	....
Granites—according to test	1000 to 2400	....	....	....
Greenwich stone	1200	....	....	....
Gneiss—New York City	1300	....	....	....
Limestone—according to test	700 to 2300	....	....	....

Allowable Unit Stresses and Loads in Accordance with the Building Laws of Various Cities.

ALLOWABLE UNIT STRESSES FOR TIMBER—EXTREME FIBER STRESS—BENDING	Pounds per Square Inch			
	New York	Chicago	Phila.	Boston
Yellow pine	1200	1250	1600	1250
White "	800	750	....	750
Spruce	800	750	1100	750
Oak	1000	1000	....	1000
Locust	1200	....	....	....
Hemlock	600	....	900	....
Chestnut	800	....	....	....
WOODEN COLUMNS OR POSTS WITH FLAT ENDS				
Yellow pine—long leaf	$1000-18\frac{L}{D}$	....	$U-\frac{UL}{100D}$	....
White, Norway pine, spruce	$800-15\frac{L}{D}$	....	"	....
Oak	$900-17\frac{L}{D}$	....	"	....
Chestnut and Hemlock	$\frac{5}{8}\left(800-15\frac{L}{D}\right)$	....	"	....
Locust	$1\frac{1}{2}$(")	....	"	....
SHEAR: Yellow pine with fiber	70	100	$66\frac{2}{3}$	100
Yellow pine, across fiber...	500	250	750	
White " with " ...	40	80	.....	80
" " across " ...	250	150	.....	
Spruce with fiber..........	50	80	50	80
" across "	320	150	500	
Oak, with "	100	150	.....	150
" across "	600	250	.....	....
Locust, with "	100	....	.....	....
" across "	720	....	.....	....
Hemlock, with "	40	....	$41\frac{2}{3}$	....
" across "	275	....	$416\frac{2}{3}$	....
Chestnut, " "	150	....	.....	....

$\frac{U}{6}$= Allowable compression in lb. per sq. inch and $\frac{L}{D}$= ratio of length to diameter in inches.

ALLOWABLE UNIT STRESSES AND LOADS IN ACCORDANCE WITH THE BUILDING LAWS OF VARIOUS CITIES—*Continued.*

ALLOWABLE UNIT SFRESSES FOR MASONRY AND BUILDING MATERIALS—Compression	Pounds per Square Inch New York	Pounds per Square Inch Chicago	Pounds per Square Inch Phila.	Pounds per Square Inch Boston
Marble—according to test	600 to 1200	....	....	....
Sandstone " "	400 to 1600	....	....	....
Bluestone—North River	2000	....	....	....
Brick—Haverstraw, flatwise	300	....	....	....
Slate	1000	....	....	....
ALLOWABLE UNIT STRESSES FOR MASONRY EXTREME FIBER STRESS—BENDING				
Granite	180	....	....	....
Greenwich stone	150	....	....	....
Gneiss—New York City	150	....	....	....
Limestone	150	....	....	....
Slate	400	....	....	....
Marble	120	....	....	....
Sandstone	100	....	....	....
Bluestone—North River	300	....	....	....
Concrete, Portland cement, 1; sand, 2; stone, 4	30	....	....	....
" " " 1; " 2; " 5	20	....	....	....
" Rosendale or equal cement, 1; sand, 2; stone, 4	16	....	....	....
" " " " 1; " 2; " 5	10	....	....	....
Brick—common	50	....	....	....
Brickwork—in cement	30	....	....	....

ALLOWABLE UNIT STRESSES FOR TIMBER

COMPRESSION

Oak, with grain	900	....	....	....
Oak, across grain	800	....	....	250
Yellow pine, with grain	1000	....	750	....
" " across grain	600	....	91⅔	250
White " with "	800	....	....	....
" " across "	400	....	....	150
Spruce, with grain	800	....	500	....
" across "	400	....	50	150
Locust, with "	1200	....	....	....
" across "	1000	....	....	....
Hemlock, with grain	500	....	350	....
" across grain	500	....	41⅔	....
Chestnut, with "	500	....	....	....
" across "	1000	....	....	....

TENSION

Yellow pine	1200	....	1800	....
White pine	800	....	....	....
Spruce	800	....	1250	....
Oak	1000	....	....	....
Hemlock	600	....	1000	....

Allowable Unit Stresses for Timber Columns in Accordance with the Building Laws of Boston and Chicago.

FOR POSTS WITH FLAT ENDS.

The stresses given in the following table, in which L=Length of post, D=Least diameter of post, and S=Stress per sq. in.

White Pine and Spruce		Long-Leaf Yellow Pine		White Oak
$\frac{L}{D}$	S	$\frac{L}{D}$	S	S
0 to 10	625	0 to 15	1000	750
10 " 35	500	15 " 30	875	650
35 " 45	375	30 " 40	750	560
45 " 50	250	40 " 45	625	470
		45 " 50	500	375

For information not given in these tables, see Complete Building Laws of the Various Cities.

GENERAL RULE FOR THICKNESS OF WALLS.
(Kidder).

An approximate rule for mercantile buildings four or more stories in height is here given:

In buildings of brick, such as is used in Boston or Chicago, the thickness of the walls should increase from the top down in series of 3 stories in the following ratio: The top three stories should be 16 in. thick; the next series, 20 in.; the next, 24 in.; the next, 28 in. For an inferior grade of brick the two upper stories only should be 16 in., the succeeding series of three increasing in the same ratio as the above.

In buildings less than 5 stories, a thickness of 12 in. for the upper story is allowable.

In specifying the thickness of walls the following should be kept in mind: First, walls of buildings intended for warehouses or mercantile use, should be thicker than those of office or apartment buildings; second, thicker walls are required for high stories and clear spans exceeding 25 ft.; third, the thickness should be increased

4 in. in every 25 ft. exceeding 100; fourth, walls whose area is not two times or more greater than the area of the openings therein should be increased in thickness; fifth, partition walls 60 ft. or less in length may be 4 in. less in thickness than the outer wall, but in no case should the thickness fall short of 8 in.

PRICES OF STEEL REINFORCEMENT.

The cost of steel is based on ¾ in. plain bars, the price for smaller bars increasing. The price at the mills in 50 ton lots is $30 a ton. If Ransome twisted bars, $4 a ton should be added for twisting. The Kahn bar, owing to its peculiar form, has more metal but does not require the bending and placing of stirrups. The manufacturers quote prices of various jobs. The cost of putting in steel for retaining walls and arches and ordinary construction varies from $5 to $8 per ton. In building work it runs up to $15 a ton. The prices for the different unit systems and special shaped bars can be obtained from the manufacturers, whose names we will gladly furnish on application.

COST OF DIFFERENT SIZES OF PLAIN RODS.

Price in cents per lb. on basis of 50-ton lots at the mill:

Size.	Bessemer rods, plain.	Open Hearth.
¾ to 3 in	1.5	1.65
⅝ to 11-16 in	1.6	1.76
½ to 9-16 in	1.7	1.86
7-16 in.	1.9	2.07
⅜ in.	2.0	2.18
5-16 in.	2.10	2.28
¼ to 9-32 in	2.2	2.39

Bids Received for Steel for Concrete Reinforcement—Glendive, Montana.

8.700 lbs. bars, square, ½-in.	$0.016	$0.018	$0.01725	$0.02	$0.016	$0.01775[1] 0.01825[2]
393.000 lbs. bars, square, ¾-in.	0.016	0.017	0.01725	0.02	0.015	0.01775[1] 0.01825[2]
16.450 lbs. bars, square, 1-in..	0.016	0.017	0.01125	0.02	0.015	0.01775[1] 0.01825[2]
8.940 lbs. bars, square, 1¼-in.	0.016	0.017	0.01725	0.02	0.015	0.01775[1] 0.01825[2]
Total....	$6,833.44	7.269.23	7.367031	8.541.80	6.415.05	7.680.86[1] 7,594.40[2]

1—Plain square bar. 2—Twisted square bar.

COST OF FORMS.

In keeping costs on forms the first cost per 1,000 ft. B. M. of lumber, the number of times used, labor cost of erecting, labor cost of oiling and patching, labor cost of wrecking, cost of labor cutting nails, etc., all expressed in M. ft. of B. M. should all be carefully kept. It is also well to keep the number of square feet of forms exposed to the concrete. A dry concrete will allow forms to be removed the next morning; however, the shores should not be removed for 4 to 6 weeks. When very wet concrete is used, forms should not be removed for 48 hours. In large arches forms are not removed in less than 14 to 28 days. Floor forms are usually left in place about a week—sometimes two weeks. By using panel construction the cost of forms can be greatly reduced. By using a laborer with 2 carpenters ordinary forms for walls, arches, etc., can be framed and erected for $10.15 per 1,000 ft. B. M.; wrecked for $2.56 per 1,000 ft. B. M. With panels the additional cost per 1,000 ft. B. M. amounts to about $0.86 for each move.

Factory buildings reinforced throughout, including footings, outside and inside columns, walls, girders, beams, floor slabs, roof and stairs, will cost $20 per cu. yd. of concrete placed. Of this, 25 to 35% will be forms, including material, erection and removal. This quotation will vary, of course, greatly, depending on price of material and labor, design and number of times the forms can be used. With proper design and good carpenters, forms can sometimes be used 3 to 4 times. On buildings with typical panels, beams and girders, and 8 to 10 stories, the forms might run to $6 a cu. yd. in places. On the other hand, a 2 or 4 story building which was very much cut up might run as high as $7 or $8 per cu. yd.

In plain floor slabs using expanded metal, Clinton wire, etc., forms may cost from $2.20 to $3.25 per cu. yd. on a 16 ft. span, and loads 400 lb. and 100 lb. respectively. For beam and plate construction (Ransome system), $5.50 to $10.50 per cu. yd., and loads 500 lb. and 100 lb. respectively.

Forms for floors cost from 4½ to 6 cents per sq. ft., including everything. Wall forms (4 in. walls) cost from 8 to 11 cents per sq. ft. of wall. Column forms 22 cents per linear ft., the quantity of concrete being 3.7 cu. yd. per 100 linear feet of column.

For floor work the prices range from 10 to 20 cents per sq. ft.; wall work, 5 cents. Of course, this is a case where the forms can be used several times.

Centering can not be furnished and removed for less than $4 per yd., and should never exceed $6 per cu. yd.

COST OF CONCRETE.

The cost of concrete depends upon the character of the construction and conditions, and not so much on the first cost of material.

When placed in large masses, when form work is a small item, it can be placed from $4 to $7. Sewers and arches, when centering is required, $7 to $14 per cu. yd. Thin walls under 8 in., $10 to $20, depending on character of construction and finish.

It always pays to obtain the best skilled labor possible, as then the minimum prices are obtainable. Quotations of cement should be obtained, cost of freight and hauling determined, and then, by multiplying the cost by the following constants the price per cu. yd. can be determined:

Proportion	1:2:4	1:2½:5	1:3:6	1:4:8
Cement required in barrels........	1.57	1.29	1.10	0.85
Sand, cu. yd..........................	0.44	0.45	0.46	0.48
Gravel or Stone, cu. yd............	0.88	0.91	0.93	0.96

In order to give a more general idea of what the various items cost in preparing, wheeling, mixing and depositing concrete, the following brief is given from Gillette's Hand-book of Cost Data:

Sand can be washed, proceeding continuously, at 5c a cu. yd. for labor, 10c per yd. for shoveling up the sand and any extra hauling. If the water is pumped, add 10c more per cu. yd. for coal and wages.

A man can load 18 to 20 cu. yd. of broken stone into a wheel barrow in 10 hours if a plank flooring is used as a dumping platform. If the materials are dumped on the ground, 12 to 14 cu. yd. From hopper-bottom cars, 14 cu. yd. per day can be unloaded by 1 man, 20 cu. yd. from flat cars. A good man can load 20 cu. yd. into a barrow;

COMPARATIVE COST OF CONCRETE (All Hand Mixed)

Material, Labor, etc.	*Miami River Bridge, Fernold, Ohio				†Ernst Street Viaduct, Cincinnati, Ohio			
	Quantity used	Price paid	Total cost	Cost per yd. of Concrete in place	Quantity used	Price paid	Total cost	Cost per yd. of Concrete in place
Cement, bbls	1156	$2 10	$2436 36	$1 58	376	$1 70	$639 00	$1 48
Sand, yds	....	.....	532 30	35	224	1 20	278 40	64
Stone	....	.....	1165 00	75	255	1 55	433 25	1 00
Lumber	....	.....	981 71	64	....	.....	173 40	40
Tools—Hardware	....	.....	307 18	20	....	.....	25 00	06
Water	....	.....	....	.....	....	.....	....	.....
Total Material	....	.....	$5422 55	3 52	....	.....	$1548 65	$3 58
Clearing—Excavating	....	.....	....	.....	....	.....	482 61	1 12
Mixing and Placing Concrete	....	.....	....	.....	....	.....	488 62	1 13
Building Forms, etc	....	.....	....	.....	....	.....	107 37	25
Pumping	....	.....	236 00	15	....	.....	....	.....
Total Labor, per day	....	1 75	4287 86	2 78	....	1 75	1082 20	2 50
Total Cost of Concrete, yd	1542	.....	$9710 41	$6 30	434	.....	$2630 85	$6 08

*One Abutment, 6 river piers, put down with cofferdams. Sand and stone close to site. Cement teamed ten miles.

†Two Abutments at street. Excavation rock and shale.

COMPARATIVE COST OF CONCRETE (All Hand Mixed)—*Continued.*

Material, Labor, etc.	*Quebec Ave. Viaduct, Cincinnati, Ohio				†C. H. & D., B. & O. Viaduct, Cincinnati, Ohio			
	Quantity used	Price paid	Total cost	Cost per yd. of Concrete in place	Quantity used	Price paid	Total cost	Cost per yd. of Concrete in place
Cement, bbls	500	$1 60	$800 00	$1 40	1908	$1 60	$3052 80	$1 44
Sand, yds	239	1 25	298 75	53	1105	95	1049 75	50
Stone	560	1 88	1046 90	1 84	1468	1 48	2172 60	1 03
Lumber	....	.....	220 70	38	....	.....	1135 80	54
Tools – Hardware	....	.....	30 44	05	....	.....	537 00	25
Water	....	.....	....	.....	....	.....	50 00	03
Total Material	....	.....	$2396 79	4 20	....	.....	$7797 95	$3 79
Clearing – Excavating	....	....	....	.....	....	.....	....	.....
Mixing and Placing Concrete	....	.....	....	.....	....	.....	....	.....
Building Forms, etc	....	.....	....	.....	....	.....	....	.....
Pumping	....	.....	....	.....	....	.....	....	.....
Total Labor, per day	....	1 75	1686 00	2 96	....	1 75	7274 67	3 44
Total Cost of Concrete, yd	570	.....	$4082 79	$7 16	2111	.....	$15272 62	$7 23

*All Pedestals 5′ x 5′ on top and from 8′ to 20′ high; location very inconvenient for delivery of materials; all team or wheelbarrow work. †One pier 56′ high; Concrete handled by steam derrick; two abutments and remainder pedestals; all materials teamed or wheeled.

COMPARATIVE COST OF CONCRETE—*Continued.*

(All Hand Mixed.)

Material, Labor, etc.	*Dam at Whitewater River, Richmond, Ind.			
	Quantity used	Price paid	Total cost	Cost per yd. of Concrete in place
Cement, bbls	204	$1 60	$326 70	$1.48½
Sand, yds	....	.....	....	.†80
Stone	....	.....	....	......
Lumber	....	.....	....	.608
Tools—Hardware	....	.....	....	.445
Water	....	.....	....	......
Total Material	....	.....	....	3.338
Clearing—Excavating	....	.....	....	.96
Mixing and Placing Concrete	...	.....	....	‡1.007
Building Forms, etc	....	.....	.....	......
Pumping	....	.....	....	.275
Total Labor, per day	....	1 50	....	2.242
Total Cost of Concrete, yd	220	.....	$1227 60	$5.58

† Sand and Gravel.
‡ Set. Forms and Mixed Concrete.
* Reinforced Concrete dam. Footings put in by aid of coffer-dams and steam pump.

a poor man, 15 cu. yd. For 1 cu. yd. of concrete, labor at 15c,

1 cu. yd. stone loaded for 11c
0.4 cu. yd. sand loaded for 4c

15c a yard

Cement can be loaded for 2c per yd., making a total of 17c.

Materials can be transported by wheelbarrows, on a steep rise, loaded with 2 sacks of Portland cement or 2 cu. ft. of stone, or on the level 3 sacks. A man can travel

200 ft. per minute and loses ¾ of a minute each trip. The following rule from Gillette's Hand-book will give a fair cost:

To a fixed cost of 4c (for lost time) add 1c for every 20 ft. of haul if runway is steep; 1c for every 30 ft. if level. Since loading the barrows is 17c, total cost is 21c, to which add 1c for every 20 or 30 ft. When horse carts are used same can be loaded in 4 minutes and dumped in 1 minute. It should travel 200 ft. per minute. The average cart carries enough stone and sand to make ½ cu. yd. of concrete. If you can get the horse, cart and driver for 30c an hour, then to 5c for lost time add 1c per 100 ft. haul.

A good workman can turn over 30 cu. yd. in 10 hours, lifting each shovel and casting it into the pile. This is 5c per cu. yd. of mortar, but as there is seldom more than 4 cu. yd. of mortar per cu. yd. of concrete we have 2c per cu. yd. for each turn given to the mortar. Giving the mortar 6 turns gives 12c; mortar and stone 3 times (3 x 5) gives 15c; total, 27c per cu. yd.; wages, 15c per hour.

Concrete, after it is mixed, can be loaded, wages 15c an hour at 12c a cu. yd. Consequently to a fixed cost of 16c (4c lost time) add 1c for every 30 ft. haul. Dumping from barrows into deep pit, same can be done for 1c a cu. yd., assuming that 1 man can dump 150 cu. yd. a day. If a small gang is working it will cost 6c per cu. yd. Cost of spreading is about 5c per cu. yd. if same is dumped from wheelbarrows; when carts are used, 10c per cu. yd. Dry concrete can be rammed for 15c per cu. yd. Spreading and ramming can be done for 40c per cu. yd. The cost of the superintendent depends on the amount of work and number of men under him and consequently can not be quoted. Where 6 men are working it would not pay to have a superintendent. To get efficiency, have two gangs, then one will try to do better than the other.

In this summary for concrete mixed by hand instead of using $1.50 for labor (same being about $2.00 at present), the following prices will result:

Loading sand, stone and cement	$0.226
Wheeling 60 ft. in barrows	0.080
Mixing concrete 6 turns	0.400
Loading concrete into barrows	0.160
Wheeling 30 ft	0.066
Dumping barrows (1 man helping)	0.066

Spreading and heavy ramming	0.200
	$1.198
Foreman at $3.00 a day	.111
Total cost of mixing 1 yd	$1.309

When machine mixing is done, batch, continuous and gravity mixers can be used. Batch mixers are revolved 10 to 15 times to give one batch a thorough mixing. This can be done in 1 to 1½ minutes after charging. A mixer can be charged, given 15 turns and discharged in about 3 minutes, or 200 batches in 10 hours; consequently the output of the mixer depends on the size of batch. With a good organization 300 batches can be turned out in 10 hours.

About 12 h. p. is used to run a ¾ yd. mixer. A gasoline engine using ten gallons of gasoline per 10 hour day at 12½c per gallon cost $1.25; 2 men will charge it, cost $4.00; 1 man to dump, cost $2.00, making a cost per cu. yd., $3.62; to this must be added the cost of wheeling to mixer, making of runs and placing same, wheeling to place of depositing, spreading, ramming, erection of hoists, engineer, cost of engine, hoist, etc., depreciation.

The price of sand and stone being obtained, the quantities required per cu. yd. can be also taken from the table and the cost found. Gravel and stone can be obtained at prices ranging from 90c to $1.60. Sand, from 50c to $1.50. Cement averages about $2 per barrel.

An experienced gang, at 15c per hour, can mix and shovel directly into place 1 cu. yd. at 80c. If wheeled, 9c per cu. yd. for the first 25 ft. and 1¼c for each additional 25 ft. should be added. A green gang will almost double this cost.

COST OF PLANT.

Hoisting engine and boiler can be rented at $2 per day for 30 days; for time exceeding 30 days a reduction of rate down to $1 per day ought to be obtainable. For fuel allow 1-3 of a ton of coal for each 10 h. p. per ten-hour shift. Prices of mixers can be obtained from manufacturers.

CONCRETE BREAKWATERS.

These are generally cast in sections and then swung into place by a derrick and grouted with Portland cement mortar. This can be placed for $6.35 per cu. yd., using a 1:2½:5 mix. In Milwaukee, where 27% of the heart of the mass above low water was natural cement concrete cost-ing $3.64 per cu. yd., the cost was reduced to $4.72 per cu. yd. in place. The Buffalo breakwater cost, when built in 36 ft. sections, blocks $7.10 per cu. yd., mass concrete $5.65 per cu. yd. When a concrete steel superstructure was built, the same cost $10.00 a cu. yd. for blocks and $9.40 a cu. yd. for mass concrete.

ABUTMENT WALLS.

When about 120 ft. long and containing 590 cu. yd., the concrete in abutment walls can be placed at $5.75 per cu. yd; day labor being $1.50 per day of 10 hours, and cement $2.10 per bbl.

RETAINING WALLS.

The excavation of these walls costs about 50c per cu. yd. A natural cement base can be put in at $4.00 per cu. yd. of 1:2:4 mix. The Portland cement concrete at $6.25 per yd.

LEVEE WALLS.

Levee walls constructed at Columbus, Ohio, 18 in. thick at the top, 50 in. at the bottom and a maximum height of 11½ ft., the heart of the wall being made of 1:2½:5 (crushed gravel). The face of the wall for a thickness of 2 in. was of mortar of 1 cement and 2 sand.

Items Used in Each cu. yd. of Concrete	Cost per cu. yd.	
	60 ft. Length	185 ft. Length
0.94 bbls. Portland cement at $2.15.	$2 021	$2 021
1.10 cu. yd. crushed gravel $.75....	0 825	0 825
.55 cu. yd. sand at $1.25............	0 687	0 687
Labor mixing, placing and ramming at $.15	1 160	1 324
Extra cost per yd. facing with 1 to 3 mortar......................	0 264	0 221
Cost of labor erecting forms.......	0 265	0 232
Cost of material in forms.....	0 379	0 391
Deterioration of tools and equipment............	0 042	0 055
	$5 643	$5 756

MORTAR AND STUCCO.

The volume of mortar needed in a cubic yard of masonry is as follows:

Brick work ⅛ in. joints	0.15	cu. yd.
Brick work ¼ in. joints	0.25	"
Brick work ½ in. joints	0.40	"
Ashlar, 20 in. courses	0.06	"
Squared stone masonry	0.20	"
Rubble masonry	0.25	"
For concrete, broken stone	0.55	"

To make a good wall plaster, take good double strength lime; slake in plenty of water. Stir the lime only enough to keep the large lumps from burning. It should stand a week or 10 days before using. Put in 2½ bushels of good clean hair to 2 barrels of lime. When ready to commence plastering take 1 barrel of good standard brand Portland cement to 3 barrels of lime. First thoroughly mix the Portland cement with 4 parts of sand; second, the lime mortar should be sanded to the right consistency to make a good rich mortar; third, mix the sanded cement with the lime mortar as it is used. It will take very little mixing to make a fine tough mortar.

For cement stucco for walls, mix 1 part of non-staining Portland cement, 2 parts medium sand, 1 part fine sand, and ½ part lime flour. When this has set hard, wet the surface thoroughly and apply the second coat with a wooden float.

For the second coat (¼ in. thick) use 1 part cement, 1 part sand and 2 parts medium sand or crushed granite. Before the second coat has set it can be jointed to present the appearance of stone work. A small addition of lime flour increases the adhesion of the mortar. The finished surface should be protected at least 2 weeks with canvas curtains or bagging saturated with water. Defects will appear if too much cement is used, if not enough moisture is applied, if not troweled sufficiently, and if not protected from variations in temperature and drafts of air.

One barrel of Portland cement covers an area as shown by the following table:

Composition of Mortar.	Thickness of Coat.	Sq. Ft. of Area Covered.
	1 in.	67
1 Cement, 1 Sand	¾ in.	90
	½ in.	134
	1 in.	104

1 Cement, 2 Sand	¾ in.	139
	½ in.	208
	1 in.	140
1 Cement, 3 Sand	¾ in.	187
	½ in.	280

A 1:2 mortar of natural cement has about the same strength that a 1:4 or 5 Portland cement mortar, and shows the following difference in price:

Portland Cement Mortar.

0.92 cu. yd. sand at $1.25	$1.15
1.12 bbls. cement at $2.50	2.80
	$3.95

Natural Cement Mortar.

0.81 cu. yd. sand at $1.25	$1.01
2.49 bbls. cement at $0.90	2.24
	$3.25

COLORING OF CONCRETE.

Dry mineral colors affect the cement least and are consequently used and are mixed according to the following table:

Color	Mineral	Lb. of Color to 100 lb. Cement	Lb. Color to Barrel Cement
Gray	Germantown Lamp Black	¼	2
Black	Manganese Dioxide	½	4.8
Black	Excelsior Carbon Black	2	...
Blue	Ultramarine	5	2.0
Green	Ultramarine Green	6	2.4
Red	Iron Oxide	6	2.4
Bright Red	Pompeian or English Red	6	2.4
Sandstone Red	Purple Oxide of Iron	6	2.4
Violet	Violet Oxide of Iron	6	2.4
Brown	Roasted Iron Oxide	6	2.4
Yellow or Buff	Yellow Ochre	6	2.4
White	Lime, White Sand or Marble; also mixture of lead and zinc salts with calc spar.		

DATA FOR ESTIMATING COST OF CUBIC YARD OF CONCRETE.—*W. A. Rogers, C. E.*

Proportion of Materials	Cost of Labor, Mixing and Placing per cu. yd.	Cost of Forms per cu. yd. (Where Forms are Required)	Materials per cu. yd.		
			Concrete	Sand	Broken Stone
1 part natural cement to 1½ parts sand to 4 parts broken stone	90 per cent of the amount paid per day for labor	From 35 cts. to 85 cts. per cu. yd.	1½ bbls.	0.35 cu.yd.	0.95 cu. yd.
1 part Portland cement to 2 parts sand to 5 parts broken stone	"	"	1⅛ bbls.	"	"
1 part Portland cement to 3 parts sand to 7½ parts broken stone	"	"	0.9 bbls.	"	"

It is best to mix the cement and color dry. Strength is gained and cost reduced by using the color cement for the surface coating only.

PROPORTIONING CONCRETE.

In this country the cement and aggregates are generally mixed by volume, although quite a number of engineers recommend a mixture by weight. This latter method is used in testing laboratories. We have mixtures specified by 1:2:3, 1:2:4, 1:2:5, 1:3:6, meaning 1 part by volume of cement, 2 parts by volume of sand and 3, 4, 5 or 6 parts by volume of stone or gravel. Frequently the sand and stone or gravel are graded together and then the mixture is expressed by 1:5, 1:6, 1:7, etc., the sand and stone being mixed to give a maximum density and then adding the cement. In the following we give Mr. Fuller's rule from Taylor & Thompson.

We find in the article of Mr. Lee Heidenreich, in the Engineering World, some sensible suggestions regarding the proportioning of concrete, as follows:

Many of the usual methods of proportioning concrete are unsatisfactory, owing to the fact that the laws governing the mixing and setting of concrete are not definitely understood. A number of formulas and rules have been devised to regulate the quantity of cement and aggregates to use per cu. yd. of concrete. The usual field practice in America is to take cement and aggregates by volume; in France, the cement is measured by weight, the aggregates by volume; in Germany both are measured by weight. In American testing laboratories, the practice is to measure cement and aggregates by weight.

Hitherto, the practice has been to mix concrete by taking 1 part cement with certain parts of sand and crushed stone or gravel. This practice is gradually changing, however, in view of the fact that the best concrete is that in which the aggregate is uniformly graded from coarse to fine. Another point in favor of abandoning the former method is that the 1:2:3 mixture of one contractor may be identical with the 1:3:5 mixture of another, owing to differences in the sizes of sand and stone. In view of this, it is preferable to abandon specifying mixtures as 1:2:3, 1:2:4, 1:3:5, but as 1:5, 1:6, 1:8, respectively in which case the 5, the 6 or the 8 parts of aggregate are mixed up, reducing the voids to whatever figure is necessary for maximum density, and then the cement added. Both methods of proportioning will be considered, since both methods are in use at the present time. The best rules governing former practice are given below.

Fuller's Rule: An approximate rule for ready calculation is the one originated by Mr. Wm. B. Fuller, and is as follows: Divide 11 by the sum of the parts (by volume) of all the ingredients; the quotient is the number of barrels of Portland cement required per cu. yd. of concrete. Multiplying this by the number of parts of sand and of stone will give the number of barrels of each. To reduce barrels to cu. yd., multiply by 0.14 (since a barrel contains 3.8 cu. ft. and there are 27 cu. ft. in a cu. yd.)

On proportioning concrete for maximum density, Mr. Fuller says:

Procure a piece of steel pipe 8 to 12 in. in diameter and a foot long and close off one end; also obtain an accurate weighing scale. Weigh out any proportions selected at random, of cement, sand and stone, and of such quantity as will fill the pipe about three-quarters full, and mix thoroughly with water on an impervious platform, such as a sheet of iron; then, standing the pipe on end, put all the concrete in the pipe, tamping it thoroughly, and where all is in, measure and record the depth of the concrete in the pipe. Now throw this concrete away, clean the pipe and tools and make up another batch with the total weight of cement, sand and stone the same as before but with the proportions of the sand to the stone slightly different. Mix and place as before and measure and record the depth in the pipe, and if the depth in the pipe is less and the concrete still looks nice and works well, this is a better mixture than the first. Continue trying in this way until the proportion has been found which will give the least depth in the pipe. This simply shows that the same amount of materials is being compacted into a smaller space and that consequently the concrete is more dense. Of course, exactly similar material must be used as are to be used on the work, and after having in this way decided on the proportions to be used on the work it is desirable to make such trials several times while the work is in progress, to be sure there is no great change in materials, or, if there is any change, to determine the corresponding change in the proportions.

The above described method of obtaining proportions does not take very much time, is not difficult, and a little trouble taken in this way will often be productive of very important results over the guess method of deciding proportions so universally prevalent.

A person interested in this method of proportioning will find on trial that other sands and stones available in the vicinity will give other depths in the pipe, and it is probable that by looking around and obtaining the best available materials the strength of the concrete obtainable will be very materially increased.

As a guide to obtaining the best concrete, the proportion of cement remaining the same, the following are the results of extensive tests:

The stone should all be of one size or should be evenly graded from fine to coarse, as an excessive amount of the fine or middle sizes is very harmful to strength.

All of the fine material smaller in diameter than one-tenth of the diameter of the largest stone should be screened out from the stone.

The diameter of the largest grains of sand should not exceed one-tenth of the diameter of the largest stone.

The coarser the stone used the coarser the sand must be, and the stronger, more dense and watertight the properly proportioned work becomes.

When small stones only are used the sand must be fine and a larger proportion of cement must be used to obtain equal strength.

A set of test beams has shown the following decrease in strength, due to decrease in density:

Proportions.	Modulus of Rupture. Lb. sq. in.
1:2:6	319
1:3:5	285
1:4:4	209
1:5:3	151
1:6:2	102
1:8:0	41

By inspecting the above table it is seen that although the amount of cement in each of the above beams was the same (namely, 1-9 of the total material), some of the beams were over 700% stronger than others.

Proportioning of mixtures can be done by means of the following formula:

$$(1) \qquad \frac{S}{C} = \frac{1}{b(1+E)}$$

$$(2) \qquad \frac{C}{G} = \frac{ab(1+E)^2}{(1+Eb)}$$

CONCRETES.

Mixtures			Required for 1 Cubic Yard Rammed Concrete											
			Stone 1 in. and under, dust screened out			Stone, 2½ in. and under, dust screened out			Stone. 2½ in., with most small stone screened out			Gravel, ¾ in. and under		
Cement,	Sand,	Stone,	Cement, barrels	Sand, cubic yds.	Stone. cubic yds.	Cement, barrels	Sand, cubic yds.	Stone. cubic yds.	Cement, barrels	Sand, cubic yds,	Stone, cubic yds.	Cement, barrels	Sand, cubic yds.	Gravel, cubic yds,
1	1.0	2.0	2.57	9.39	0.78	2.63	0.40	0.80	2.72	0.41	0.83	2.30	0.35	0.74
1	1.0	2.5	2.29	0.35	0.70	2.34	0.36	0.89	2.41	0.37	0.92	2.10	0.32	0.80
1	1.0	3.0	2.06	0.31	0.94	2.10	0.32	0.96	2.16	0.33	0.98	1.89	0.29	0.86
1	1.0	3.5	1.84	0.28	0.98	1.88	0.29	1.00	1.88	0.29	1.05	1.71	0.26	0.91
1	1.5	2.5	2.05	0.47	0.78	2.09	0.48	0.80	2.16	0.49	0.82	1.83	0.42	0.73
1	1.5	3.0	1.85	0.42	0.84	1.90	0.43	0.87	1.96	0.45	0.89	1.71.	0.39	0.78
1	1.5	3.5	1.72	0.39	0.91	1.74	0.40	0.93	1.79	0.41	0.96	1.57	0.36	0.83
1	1.5	4.0	1.57	0.36	0.96	1.61	0.37	0.98	1.64	0.38	1.00	1.46	0.33	0.88
1	1.5	4.5	1.43	0.33	0.98	1.46	0.33	1.00	1.51	0.35	1.06	1.34	0.31	0.91
1	2.0	3.0	1.70	0.52	0.77	1.73	0.53	0.79	1.78	0.54	0.81	1.54	0.47	0.73
1	2.0	3.5	1.57	0.48	0.83	1.61	0.49	0.85	1.66	0.50	0.88	1.44	0.44	0.77
1	2.0	4.0	1.46	0.44	0.89	1.48	0.45	0.90	1.53	0.47	0.93	1.34	0.41	0.81
1	2.0	4.5	1.36	0.42	0.93	1.38	0.42	0.95	1.43	0.43	0.98	1.26	0.38	0.86
1	2 0	5.0	1.27	0.39	0.97	1.29	0.39	0.98	1.33	0.39	1.03	1.17	0.36	0.89

1	2.5	3.5	1.45	0.55	0.77	1.48	0.56	0.79	1.51	0.58	0.81	1.32	0.50	0.70
1	2.5	4.0	1.35	0.52	0.82	1.38	0.53	0.84	1.42	0.54	0.87	1.24	0.47	0.75
1	2.5	4.5	1.27	0.48	0.87	1.29	0.49	0.88	1.33	0.51	0.91	1.16	0.44	0.80
1	2.5	5.0	1.19	0.46	0.91	1.21	0.46	0.92	1.26	0.48	0.96	1.10	0.42	0.83
1	2.5	5.5	1.13	0.43	0.94	1.15	0.44	0.96	1.18	0.44	0.99	1.03	0.39	0.86
1	2.5	6.0	1.07	0.41	0.97	1.07	0.41	0.98	1.10	0.41	1.03	0.98	0.37	0.89
1	3.0	4.0	1.26	0.58	0.77	1.28	0.58	0.78	1.32	0.60	0.80	1.15	0.52	0.72
1	3.0	4.5	1.18	0.54	0.81	1.20	0.55	0.82	1.24	0.57	0.85	1.09	0.50	0.75
1	3.0	5.0	1.11	0.51	0.85	1.14	0.52	0.87	1.17	0.54	0.89	1.03	0.47	0.78
1	3.0	5.5	1.06	0.48	0.89	1.07	0.49	0.90	1.11	0.51	0.93	0.97	0.44	0.81
1	3.0	6.0	1.01	0.46	0.92	1.02	0.47	0.93	1.06	0.48	0.97	0.92	0.42	0.84
1	3.0	6.5	0.96	0.44	0.95	0.98	0.44	0.96	1.00	0.45	1.01	0.88	0.40	0.87
1	3.0	7.0	0.91	0.42	0.97	0.92	0.42	0.98	0.94	0.42	1.05	0.84	0.38	0.89
1	3.5	5.0	1.05	0.56	0.80	1.07	0.57	0.82	1.11	0.59	0.85	0.96	0.50	0.76
1	3.5	5.5	1.00	0.53	0.84	1.02	0.54	0.85	1.06	0.56	0.89	0.92	0.48	0.78
1	3.5	6.0	0.95	0.50	0.87	0.97	0.51	0.89	1.00	0.53	0.92	0.88	0.46	0.80
1	3.5	6.5	0.92	0.49	0.91	0.93	0.49	0.92	0.96	0.51	0.95	0.83	0.44	0.82
1	3.5	7.0	0.87	0.47	0.93	0.89	0.47	0.95	0.91	0.49	0.98	0.80	0.43	0.85
1	3.5	7.5	0.84	0.45	0.96	0.86	0.45	0.98	0.86	0.47	1.01	0.76	0.41	0.87
1	3.5	8.0	0.80	0.42	0.97	0.82	0.43	1.01	0.81	0.45	1.04	0.73	0.39	0.89
1	4.0	6.0	0.90	0.55	0.82	0.92	0.56	0.84	0.95	0.58	0.87	0.83	0.51	0.77
1	4.0	6.5	0.87	0.53	0.85	0.88	0.53	0.87	0.91	0.55	0.90	0.80	0.49	0.79
1	4.0	7.0	0.83	0.51	0.89	0.84	0.51	0.90	0.87	0.53	0.93	0.77	0.47	0.81
1	4.0	7.5	0.80	0.49	0.91	0.81	0.50	0.93	0.84	0.51	0.96	0.73	0.44	0.83
1	4.0	8.0	0.77	0.47	0.93	0.78	0.48	0.95	0.81	0.49	0.98	0.71	0.43	0.86
1	4.0	8.5	0.74	0.45	0.95	0.76	0.46	0.98	0.78	0.47	1.01	0.68	0.42	0.88
1	4.0	9.0	0.71	0.43	0.97	0.73	0.44	1.01	0.75	0.45	1.04	0.65	0.40	0.89
1	5.0	9.0	0.66	0.50	0.90	0.67	0.52	0.93	0.70	0.52	0.96	0.61	0.46	0.83
1	5.0	10.0	0.62	0.47	0.95	0.63	0.48	0.96	0.65	0.50	1.00	0.57	0.43	0.87

C = the volume of cement paste in a unit volume of concrete.

S = volume of sand.
G = volume of stone or gravel.
E = percentage of excess, generally about 10%.
a = percentage of voids in stone or gravel.
b = percentage of voids in sand.

For a detailed discussion, see Buel & Hill, page 484. This can be compared with William B. Fuller's formula given in Taylor & Thompson.

c = number of parts of cement.
s = number of parts of sand.
g = number of parts of gravel or broken stone.

Then $\frac{11}{c+s+g}=P=$ number of barrels of cement per cu. yd. concrete.

$P\times S\times\frac{3.8}{27}=$ number of cu. yds. of sand per cu. yds. concrete.

$P\times g\times\frac{3.8}{27}=$ number of cu. yds. of stone per cu. yds concrete

Materials for One Cubic Yard of Concrete.

(TAYLOR & THOMPSON.)

Proportions	Cement, Barrels	Sand Cu. Yds.	Gravel or Stone, Cu. Yds.
1:2:4	1.57	0.44	0.88
1:2½:5	1.29	0.45	0.91
1:3:6	1.10	0.46	0.93
1:4:8	0.85	0.48	0.96

The following suggestions are taken from a pamphlet issued by the Marquette Portland Cement Co.:

Character of Materials to be Used with Cement: Sand should be clean, coarse and sharp. A loamy sand should not be used; it will give bad results and retard the set. A very fine sand or gravel should be avoided; it will weaken the work. Gravel should be clean and vary from ¼ in. to 2 in. in size. Care must be taken, if work is being done in winter time, that the material is kept from freezing, and that warm water is used, instead of cold, for mixing concrete. Crushed stone should be clean and free from dust or dirt.

Mixing Concrete: Mix cement and sand dry until the mixture shows a uniform color, then place the stone on top, wet slightly and mix well together by shoveling over three or four times; add only sufficient water to make the sand and cement stick to the stone, so that when handled by a shovel it will not crumble or fall off. Too much water weakens concrete.

Proportions for Concrete Work: Varying proportions of sand and stone can be mixed with one part of cement and give good results, but for all ordinary purposes, such as sub-surfaces of sidewalks, cellars or street paving, mill or machinery foundations, house foundations, retaining walls, cisterns, reservoirs, etc., one part cement, two parts of sand and five parts of broken stone, or one part of cement, three parts of sand and seven parts of broken stone will give excellent results; enough sand should be used to fill all the voids between the stones. Architects usually state the proportions for the concrete in building specifications, and vary the proportions of sand and stone to suit the character of the work. If absolutely watertight work is required, the face of concrete should be plastered on the side facing the water with a mixture of one and one-half parts of sand to one part cement. Never mix large quantities, but only as much as can be put in place within fifteen or twenty minutes after mixing.

Laying Work: Ram the mixture well into place with a tamping iron or heavy wooden rammer, until it shakes like jelly and until the water comes to the surface; lay quickly, so that the layers adhere to each other, and in cold weather, to avoid freezing, use 1 lb. of salt to 15 or 18 gal. of water. In hot weather, after concrete has set (say 12 hours) wet frequently with water, especially on sidewalk work. Cover unfinished work over night or over Sunday to prevent surface drying out, thus insuring a good joint when work is resumed.

Laying Pavements: Depth of excavation depends greatly on soil; if walks are bounded on each side by soil, 15 to 18 in. should be excavated and filled up to within 4 in. of level with good ashes, clinker, gravel or stone sprinkled and rammed well; this is necessary to prevent frost getting under pavement. Stakes and strips (2 in. x 4 in.) should be set on the outside to keep the walk straight; then fill to within ½ in. of top strips with concrete, mixed proportionately as stated in "Proportions for Concrete Work;" ram well, as previously directed; before the sub-

Proportions of Ingredients Adopted in Europe—(Marsh).

Mixture	Quantities necessary to make 1 cubic yard of Concrete			Proportions in cubic ft. of Aggregates per bag of 224 lbs. cement	
	Cement, pounds	Sand, cubic ft., measured loose	Stone, cubic ft., measured loose	Sand, cubic ft.	Stone, cubic ft.
That very generally employed for columns, beams and slabs	505	10.78	21.56	4.31	8.62
Used by some constructors for the same pieces	560	10.78	21.56	4.00	8.00
Employed by M. Considere for hooped Concrete with a resistance of 1,000 lbs. per square inch	560	10.78	21.56	4.00	8.00
Employed by M. Considere for hooped Concrete with a resistance of 1,425 lbs. per square inch and for piles	757	10.78	21.56	2.96	5.92

surface is hard-set, fill the remaining ½ in. with top surface, which is generally composed of 1 part of cement to 1 or 2 of good sand, or coarsely ground marble dust or limestone, or trap rock screened to from 1-16 to ⅛ in. in size. Obtain an even surface by working the top dressing backward and forward with the edge of a level board, which should rest on the strips on each side of the walk; when it is worked sufficiently to fill all pores, trowel until water comes to top; allow sufficient time for water to disappear, then trowel again and get even surface. Too much troweling is objectionable. Blocks should be laid in 4 or 5 ft. squares; lay every other block, returning to lay intervening blocks when the first ones are sufficiently set to allow strips being removed. Tar paper should be laid between joints to prevent the sections adhering to each other. Never use pure cement for dusting, but use equal parts of cement and sand. Dusting should be avoided and only done in cases where it is found too much water has been added to the mixture. Protect the surface against hot rays of sun and against currents of air. Two to 4 in. of earth, kept moist, makes a good cover, but is liable to stain the walk.

Walks laid according to the above rule will require 7 to 8 lb. of cement to the square foot. Curbs and gutters should be made in one that they may bind together, and should be made in lengths of 4 or 5 ft. each; the facing or curbing should be finished with a coating of 1 part cement to 1 of sand, carefully worked and troweled as soon as the boards can be removed to admit of same; the edges should be leveled off.

Cellar Floors: With the exception of the remarks above on depth of excavation, the directions for pavements apply to cellar floors.

Mortar: For masonry and brick-work use 1 part of cement to 5 or 6 parts of clean, sharp sand, adding about ½ part of fresh slacked lime to give the mortar a plastic nature; add more lime if necessary.

SPECIFICATIONS.

What Specifications for Reinforced Concrete Require. Work Included: This consists of the portion of the structure indicated on the plans and is either monolithic or of reinforced concrete. It embraces, providing all materials and labor to construct and complete the work, making and placing of forms, bending and placing of steel, mixing and placing of concrete, removal of forms, removing rubbish and finishing of surfaces. Full detail drawings, showing column sizes, thickness of slabs and sizes of beams and girders are generally made part of the specifications. These can be replaced by some special system guaranteed to be as good as the one shown by the architects.

Forms: The forms should be of such a character that after they are removed all slabs will have plane level surfaces, all beams, girders, columns and walls will line up true to a plumb line and have the proper elevations called for. Wherever a surface finish is to be used rough lumber can be used on that side. The size, thickness and quality of the lumber is generally left to the discretion of the contractor, as it is to his interest to use the best quality of lumber of the necessary dimensions.

The forms should not be removed until the concrete has become hard enough to sustain its own weight and the probable weight liable to be superimposed. Shores should be left in place at least 4 weeks.

Before concreting, all forms should be cleaned of sawdust, blocks, shavings, dirt, dust, holes patched with tin, oiled and sprinkled. Holes should be left in the bottom of columns to clean out the pieces of wood and sawdust that collect in same.

Concrete: The concrete is required to be mixed by volume; 1:3:6 being required for footings and 1:2:4 for structural members, 1:2 for finish and this should never be less than ¾ in. Water enough to make a pasty mixture is required. Never use such an amount of water that the cement and sand runs away from the stone or gravel. (Note.—By 1:3:6 is meant 1 part cement, 3 parts sand and 6 parts by volume of broken stone or gravel). It is advisable to test the mixture for maximum density.

Portland Cement: Only high grade, established brands of cement, delivered at least 12 days before being used and passing the following tests should be used:

Specific gravity of the cement, thoroughly dried at 100° C. to be at least 3.10.

Fineness: It should leave a residue of not more than 8% on a No. 100 and not more than 25% on a No. 200 sieve.

Time of Setting: Initial set not less than 30 minutes; hard set not less than 1 hour, nor more than 10 hours.

Tensile Strength: A briquette of 1 sq. in. cross section shall have the following strengths:

Neat Cement.	Strength
24 hours in moist air	150 to 200 lb.
7 days (1 day in moist air, 6 days in water)	450 to 550 lb.
28 days (1 day in moist air, 27 days in water)	550 to 650 lb.

One Part Cement, Three Parts Sand.

7 days (1 day in moist air, 6 days in water)..150 to 200 lb.
28 days (1 day in moist air, 27 days in water) 200 to 300 lb.

Constancy of Volume: Pats of neat cement, about 3 in. in diameter, ½ in. thick at center and tapering to a thin edge, shall be kept in moist air for a period of 24 hours. Keep one pat in air at normal temperatures and observe at intervals of at least 28 days. Keep another pat in water at 70° F. and observe at intervals of 28 days. Expose another pat to an atmosphere of steam, above boiling water, for 5 hours. The pats during this test should remain firm and hard and show no signs of cracking, checking or disintegrating.

Sulphuric Acid and Magnesia: No more than 1.75% of anhydrous sulphuric acid nor more than 4% of magnesia should be present.

If cements do not fill the 24 hour or 7 day tests and are held for the 28 day tests and then fail to come up to the above requirements they should be condemned and immediately removed from the premises.

For a more complete test of cement, see the U. S. Government Specifications.

Sand: All sand shall be clean, sharp sand, not having an excessive amount of foreign material in the form of loam or clay; 10% can be allowed.

Broken Stone: Stone should pass a ¾ in. ring for small work, 1½ for large work; screenings, if clean, are permitted. All stone should be free from dirt which might keep the cement from adhering to the stone. Sandstone, limestone, granite, trap rock or other stone can be used.

Gravel: Gravel should be not larger than that passing a ¾ in. ring and shall contain no sand, unless the proportion of sand in the mixture used is reduced. It shall also be free from clay, loam and other extraneous material.

Mixing and Placing: The mixing can either be done by hand, the cement, sand and stone being placed on a watertight mixing board, or mixed in a batch mixer. The proportion of water determined according to the nature of the materials being mixed to give same a good, pasty, well mixed consistency.

The concrete shall be handled quickly and brought to the points of placing by hoists, derricks, concrete buggies or wheelbarrows, proper runs being supplied so that the steel may not be displaced. Note that all steel has its proper position before concreting.

When filling columns fill same to bottom of beams or girders. Churn same thoroughly with a long pole so as to work the concrete into close contact with the reinforcement. After being allowed to set for several hours the beams and slabs may be placed. Column forms are to be filled before the reinforcement for beams and slabs is in place.

Reinforcement: All steel should be medium steel, having an ultimate tensile strength of from 60,000 to 68,000 lb. per sq. in. and an elastic limit of not less than ½ the ultimate strength and should elongate not less than 22% in 8 in. and bend cold 180° around a diameter equal to the thickness of the piece tested without fracture on outside of bend. If high carbon steel is used it should contain not more than 0.06% of phosphorus; not more than 0.8% of sulphur; not less than 0.4% or more than 0.8% of manganese and should contain from 0.5 to 0.6% of carbon. Its ultimate tensile strength should be at least 100,000 lb. per sq. in.; elastic limit of half the ultimate strength, elongation of 10% in 8 in. for a test piece of ⅜ in. to ¾ in. in diameted. A ½ in. test piece should bend 110° without fracture around a piece of equal diameter.

Steel in compression should have a working value of 10,000 lb. per sq. in.

In shear 10 to 12,000 lb. per sq. in. is allowable.

All bars for column reinforcement should be cut with square or milled ends, especially if they are over 1½ in. diameter.

All steel should be bent as per details furnished. Most companies have a standard system of bending.

All stirrups should be placed in the position shown on drawings and never placed a greater distance than the effective depth of the beam.

The column hoops or spirals should be properly spaced and wired to the vertical steel, depending on the size of the column and never exceeding the diameter of the column less 4 in. Before putting column steel on footings, the bearing plates should be properly grouted in place and all sawdust or rubbish removed. No more steel should be placed until the columns have been concreted. Beam, girder and slab steel is next placed and should be properly wired to secure it in its desired position. Before concreting examine all steel to make certain none of its has been pushed out of position or omitted.

Patching and Finishing: After forms are removed, any surfaces in the concrete not properly filled are to be gone over with cement mortar and finished with a wood or cork float, rubbed with stone, chipped, stuccoed or some other manner. Frequently a tarred paint or waterproofing compound is used.

SPECIFICATIONS FOR ARTIFICIAL STONE.

In making artificial stone the following specifications should be followed:

No concrete should be used that has been wet over 30 minutes.

Proportion of water uniform.

Thorough mixing, so that there is an absence of porosity and permeability of block reduced by added density and thereby overcoming efflorescence.

Curing: In curing, the application of moisture should be made regularly and uniformly so that the final set may take place under the most favorable conditions, thus insuring the greatest strength.

Blocks treated with varying degrees of moisture or exposure to the sun causing variation in contraction and thus producing hair cracks should not be accepted. Blocks or sections of molded stone should be sprinkled at regular intervals and so frequently that no drying takes place. They should not be allowed to turn white during curing. Blocks made by the dry process should be carefully cured for at least 20 days. Blocks made from a medium mixture 7 to 10 days. When a wet mixture is used little water will be necessary in curing, but uniform conditions must be maintained and the stone sheltered from the sun. If blocks are cured in a live steam room same can be used after 4 days.

Facing: The facing of the blocks should be done with a 1:2 mixture of cement and sharp fine white sand and should be 1 in. in thickness. This facing should be applied before the backing takes its set and not be troweled so that the neat cement is drawn to the surface and resulting in hair cracks. In mixing, the facing should not be allowed to become lumpy and the wet mixture should be screened if necessary. A little more water than usual should be used in the body of the block so as to insure the moisture staying in the facing.. No interval of time should elapse between the making of the body and the facing of the artificial stone. Direct compression of the face should be obtained. If coloring matter is used only mineral colors should be used.

Tests: Tests should be made on 28 day specimens to determine the character of the sand, gravel or broken stone.

Body of Stone: The body of the stone should be made of a 1:2:4 mixture of an established brand of Portland cement, clean sharp sand and gravel or stone passing through a ½ in. ring. Enough water to insure a good bonding mixture should be used.

Laying: Before laying the various pieces the adjoining work should be thoroughly moistened so as to prevent absorption of the water out of the mortar. This mortar should be composed of 1 part cement, 3 parts of sand and 1 part of slaked lime. If the stone is cast in place the forms should be sandpapered, shellacked, sprinkled and oiled, a 1:2 mixture ½ in. thick placed next to the forms and the backing of a very wet 1:2:4 mixture then added. Troweling should not be allowed on the face, as checks and hair cracks would result.

Corners, etc.: All corners and edges shall be sharp and well defined. They shall have true horizontal or vertical lines, and no stone will be accepted that is chipped or marred in any way. Where the corners or edges are apt to be struck a piece of galvanized iron bent in the shape of a written small i shall be used.

Reinforcement: When pinnacles, base courses, balusters, railings, etc., shall be liable to crack, due to shrinkage stresses, the same should be reinforced by the proper amount of steel to prevent such cracks.

Discoloration: All artificial stone should have a uniform color and should be made of such cements that there will be no efflorescence. Cement of the same color only should be used to prevent streaking. The sand should also have the same shade of color.

STANDARD SPECIFICATIONS FOR CEMENT.

General Conditions.

1. All cement shall be inspected.
2. Cement may be inspected either at the place of manufacture or on the work.
3. In order to allow ample time for inspecting and test-

ing, the cement should be stored in a suitable weather-tight building having the floor properly blocked or raised from the ground.

4. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment.

5. Every facility shall be provided by the contractor and a period of at least 12 days allowed for the inspection and necessary tests.

6. Cement shall be delivered in suitable packages with the brand and name of manufacturer plainly marked thereon.

7. A bag of cement shall contain 94 lb. of cement net. Each barrel of Portland cement shall contain 4 bags, and each barrel of natural cement shall contain 3 bags of the above net weight.

8. Cement failing to meet the 7-day requirements may be held awaiting the results of the 28-day tests before rejection.

9. All tests shall be made in accordance with the methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, presented to the Society January 21, 1903, and amended January 20, 1904, with all subsequent amendments thereto. (See addendum to these specifications.)

10. The acceptance or rejection shall be based on the following requirements:

NATURAL CEMENT.

11. **Definition.** This term shall be applied to the finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas.

Specific Gravity.

12. The specific gravity of the cement thoroughly dried at 100° C., shall be not less than 2.8.

Fineness.

13. It shall leave by weight a residue of not more than 10% on the No. 100, and 30% on the No. 200 sieve.

Time of Setting.

14. It shall develop initial set in not less than 10 minutes, and hard set in not less than 30 minutes, nor more than 3 hours.

Tensile Strength.

15. The minimum requirements for tensile strength for briquettes 1 in. square in cross section shall be within the following limits, and shall show no retrogression in strength within the periods specified:*

Age.	Strength.
Neat Cement.	
24 hours in moist air	50-100 lb.
7 days (1 day in moist air, 6 days in water)	100-200 lb.
28 days (1 day in moist air, 27 days in water)	200-300 lb.
One Part Cement, Three Parts Standard Sand.	
7 days (1 day in moist air, 6 days in water)	25- 75 lb.
28 days (1 day in moist air, 27 days in water)	75-150 lb.

Constancy of Volume.

16. Pats of neat cement about 3 in. in diameter, ½ in. thick at center, tapering to a thin edge, shall be kept in moist air for a period of 24 hours.

(a) A pat is then kept in air at normal temperature.

(b) Another is kept in water maintained as near 70° F. as practicable.

17. These pats are observed at intervals for at least 28 days, and, to satisfactorily pass the tests, should remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

PORTLAND CEMENT.

18. **Definition.** This term is applied to the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than 3% has been made subsequent to calcination.

Specific Gravity.

19. The specific gravity of the cement, thoroughly dried at 100° C., shall be not less than 3.10.

Fineness.

20. It shall leave by weight a residue of not more than 8% on the No. 100, and not more than 25% on the No. 200 sieve.

Time of Setting.

21. It shall develop initial set in not less than 30 min-

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*For example, the minimum requirement for the 24 hour neat cement test should be some value within the limits of 50 and 100 lb., and so on for each period stated.

utes, but must develop hard set in not less than 1 hour, nor more than 10 hours.

Tensile Strength.

22. The minimum requirements for tensile strength for briquettes 1 in. square in section shall be within the following limits, and shall show no retrogression in strength within the periods specified:[*]

Age.	Neat Cement.	Strength.
24 hours in moist air		150-200 lb.
7 days (1 day in moist air, 6 days in water)		450-550 lb.
28 days (1 day in moist air, 27 days in water)		550-650 lb.
	One Part Cement, Three Parts Sand.	
7 days (1 day in moist air, 6 days in water)		150-200 lb.
28 days (1 day in moist air, 27 days in water)		200-300 lb.

Constancy of Volume.

23. Pats of neat cement about 3 in. in diameter, ½ in. thick at the center, and tapering to a thin edge, shall be kept in moist air for a period of 24 hours.

(a) A pat is then kept in air at normal temperature and observed at intervals for at least 28 days.

(b) Another pat is kept in water maintained as near 70° F. as practicable, and observed at intervals for at least 28 days.

(c) A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours.

24. These pats, to satisfactorily pass the requirements, shall remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

Sulphuric Acid and Magnesia.

25. The cement shall not contain more than 1.75% of anhydrous sulphuric acid (SO 3), nor more than 4% of magnesia (MgO).

ADDENDUM.

ABSTRACT OF METHODS RECOMMENDED BY THE SPECIAL COMMITTEE ON UNIFORM TESTS OF CEMENT OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Sampling.

1. **Selection of Sample:** The sample shall be a fair av-

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[*] For example, the minimum requirement for the 24 hour neat cement test should be some value within the limits of 150 and 200 lb., and so on for each period stated.

PERCENT OF WATER FOR CEMENT MORTARS OF NORMAL CONSISTENCY.

(Suggested by American Society for Testing Materials.)

Percentage of Water for Neat Cement	Percentage of Water for Sand Mortars					Percentage of Water for Neat Cement	Percentage of Water for Sand Mortars				
	Proportions Cement to Sand by Weight						Proportions Cement to Sand by Weight				
	1:1	1:2	1:3	1:4	1:5		1:1	1:2	1:3	1:4	1:5
18	12.0	10.0	9.0	8.4	8.0	33	17.0	13.3	11.5	10.4	9.6
19	12.3	10.2	9.2	8.5	8.1	34	17.3	13.6	11.7	10.5	9.7
20	12.7	10.4	9.3	8.7	8.2	35	17.7	13.8	11.8	10.7	9.9
21	13.0	10.7	9.5	8.8	8.3	36	18.0	14.0	12.0	10.8	10.0
22	13.3	10.9	9.7	8.9	8.4	37	18.3	14.2	12.2	10.9	10.1
23	13.7	11.1	9.8	9.1	8.5	38	18.7	14.4	12.3	11.1	10.2
24	14.0	11.3	10.0	9.2	8.6	39	19.0	14.7	12.5	11.2	10.3
25	14.3	11.6	10.2	9.3	8.8	40	19.3	14.9	12.7	11.3	10.4
26	14.7	11.8	10.3	9.5	8.9	41	19.7	15.1	12.8	11.5	10.5
27	15.0	12.0	10.5	9.6	9.0	42	20.0	15.3	13.0	11.6	10.6
28	15.3	12.2	10.7	9.7	9.1	43	20.3	15.6	13.2	11.7	10.7
29	15.7	12.5	10.8	9.9	9.2	44	20.7	15.8	13.3	11.9	10.8
30	16.0	12.7	11.0	10.0	9.3	45	21.0	16.0	13.5	12.0	11.0
31	16.3	12.9	11.2	10.1	9.4	46	21.3	16.1	13.7	12.1	11.1
32	16.7	13.1	11.3	10.3	9.5						

erage of the contents of the package; it is recommended that, where conditions permit, one barrel in every 10 be sampled.

2. All samples should be passed through a sieve having 20 meshes per linear in., in order to break up lumps and remove foreign material; this is also a very effective method for mixing them together in order to obtain an average. For determining the characteristics of a shipment of cement, the individual samples may be mixed and the average tested; where time will permit, however, it is recommended that they be tested separately.

3. **Method of Sampling:** Cement in barrels should be sampled through a hole made in the center of one of the staves, midway between the heads, or in the head, by means of an auger or a sampling iron similar to that used by sugar inspectors. If in bags, it should be taken from surface to center.

Chemical Analysis.

4. **Method:** As a method to be followed for the analysis of cement, that proposed by the Committe on Uniformity in the Analysis of Materials for the Portland Cement Industry, of the New York Section of the Society for Chemical Industry, and published in the Journal of the Society for January 15, 1902, is recommended.

Specific Gravity.

5. **Apparatus and Method:** The determination of specific gravity is most conveniently made with Le Chatelier's apparatus. This consists of a flask (*D*), Fig. 1, of 120 cu. cm. (7.32 cu. in.) capacity, the neck of which is about 20 cm. (7.87 in.) long; in the middle of this neck is a bulb (*C*), above and below which are two marks (*F*) and (*E*); the volume between these marks is 20 cu. cm. (1.22 cu. in.). The neck has a diameter of about 9 mm. (0.35 in.), and is graduated into tenths of cubic centimeters above the mark (*F*).

6. Benzine (62° Baume naphtha), or kerosene free from water, should be used in making the determination.

7. The specific gravity can be determined in two ways: (1) The flask is filled with either of these liquids to the lower mark (*E*) and 64 gr. (2.25 oz.) of powder, previously dried at 100° C. (212° F.) and cooled to the temperature of the liquid, is gradually introduced through the funnel (*B*) [the stem of which extends into the flask to the top of the bulb (*C*)], until the upper mark (*F*) is reached. The difference in weight between the cement

remaining and the original quantity (64 gr.) is the weight which has displaced 20 cu. cm.

8. (2) The whole quantity of the powder is introduced, and the level of the liquid rises to some division of the graduated neck. This reading plus 20 cu. cm. is the volume displaced by 64 gr. of the powder.

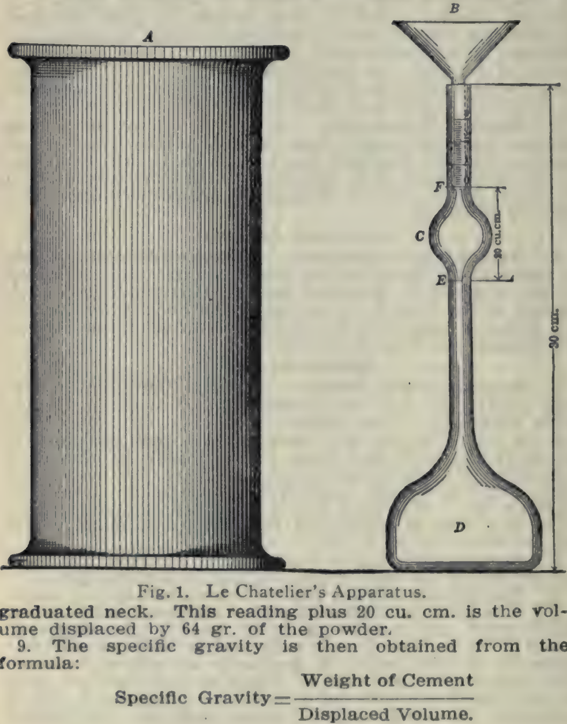


Fig. 1. Le Chatelier's Apparatus.

9. The specific gravity is then obtained from the formula:

$$\text{Specific Gravity} = \frac{\text{Weight of Cement}}{\text{Displaced Volume.}}$$

10. The flask, during the operation, is kept immersed in water in a jar (*A*), in order to avoid variations in the temperature of the liquid. The results should agree within 0.01.

11. A convenient method for cleaning the apparatus is as follows: The flask is inverted over a large vessel, preferably a glass jar, and shaken vertically until the liquid starts to flow freely; it is then held still in a vertical position until empty; the remaining traces of cement can be removed in a similar manner by pouring into the flask a small quantity of clean liquid and repeating the operation.

Fineness.

12. **Apparatus:** The sieves should be circular, about 20 cm. (7.87 in.) in diameter. 6 cm. (2.36 in.) high, and provided with a pan. 5 cm. (1.97 in.) deep, and a cover.

13. The wire cloth should be woven (not twilled) from brass wire having the following diameters:

No. 100, 0.0045 in.; No. 200, 0.0024 in.

14. This cloth should be mounted on the frames without distortion; the mesh should be regular in spacing and be within the following limits:

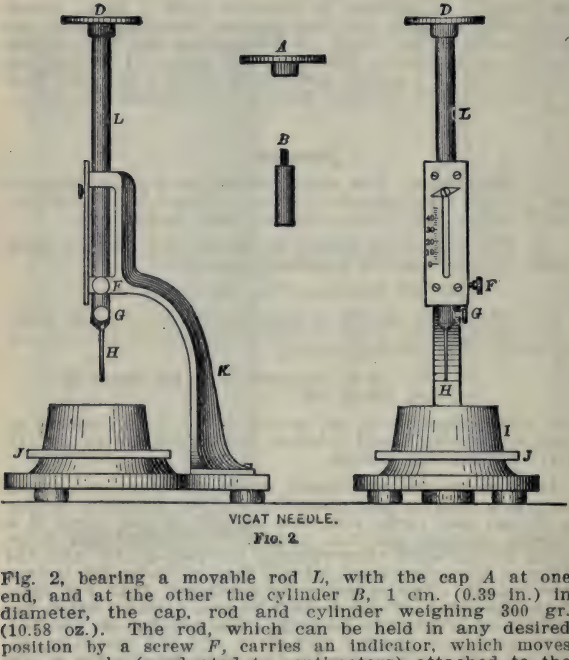
No. 100, 96 to 100 meshes to the linear in.
No. 200, 188 to 200 " " " "

15. Fifty gram. (1.76 oz.) or 100 gr. (3.52 oz.) should be used for the test, and dried at a temperature of 100° C. (212° F.) prior to sieving.

16. **Method:** The thoroughly dried and coarsely screened sample is weighed and placed on the No. 200 sieve, which, with pan and cover attached, is held in one hand in a slightly inclined position, and moved forward and backward, at the same time striking the side gently with the palm of the other hand, at the rate of about 200 strokes per minute. The operation is continued until not more than one-tenth of 1 per cent passes through after one minute of continuous sieving. The residue is weighed, then placed on the No. 100 sieve and the operation repeated. The work may be expedited by placing in the sieve a small quantity of large shot. The results should be reported to the nearest tenth of 1 per cent.

Normal Consistency.

17. **Method:** This can best be determined by means of Vicat Needle Apparatus, which consists of a frame *K*,



VICAT NEEDLE.

FIG. 2.

Fig. 2, bearing a movable rod *L*, with the cap *A* at one end, and at the other the cylinder *B*, 1 cm. (0.39 in.) in diameter, the cap, rod and cylinder weighing 300 gr. (10.58 oz.). The rod, which can be held in any desired position by a screw *F*, carries an indicator, which moves over a scale (graduated to centimeters) attached to the frame *K*. The paste is held by a conical, hard-rubber ring (I),. 7 cm. (1.76 in.) in diameter at the base, 4 cm.

(1.57 in.) high, resting on a glass plate *J*, about 10 cm. (3.94 in.) square.

18. In making the determination, the same quantity of cement as will be subsequently used for each batch in making the briquettes (but not less than 500 grams) is kneaded into a paste, as described in paragraph 39, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained 6 in. apart; the ball is then pressed into the rubber ring, through the larger opening, smoothed off, and placed (on its large end) on a glass plate and the smaller end smoothed off with a trowel; the paste, confined in the ring, resting on the plate, is placed under the rod bearing the cylinder, which is brought in contact with the surface and quickly released.

19. The paste is of normal consistency when the cylinder penetrates to a point in the mass 10 mm. (0.39 in.) below the top of the ring. Great care must be taken to fill the ring exactly to the top.

20. The trial pastes are made with varying percentages of water until the correct consistency is obtained.

Note. The Committee on Standard Specifications inserts the table on page 121 for temporary use to be replaced by one to be devised by the Committee on the American Society of Civil Engineers.

Time of Setting.

21. **Method:** For this purpose the Vicat Needle, which has already been described in paragraph 17, should be used.

22. In making the test, a paste of normal consistency is molded and placed under the rod *L*, Fig. 2, as described in paragraph 18; this rod, bearing the cap *D* at one end and the needle *H*, 1 mm. (0.039 in.) in diameter, at the other, weighing 300 gr. (10.58 oz.). The needle is then carefully brought in contact with the surface of the paste and quickly released.

23. The setting is said to have commenced when the needle ceases to pass a point 5 mm. (0.20 in.) above the upper surface of the glass plate, and is said to have terminated the moment the needle does not sink visibly into the mass.

24. The test pieces should be stored in moist air during the test; this is accomplished by placing them on a rack over water contained in a pan and covered with a damp

PERCENTAGE OF WATER FOR STANDARD MIXTURES.

Neat	1-1	1-2	1-3	1-4	1-5	Neat	1-1	1-2	1-3	1-4	1-5
18	12.0	10.0	9.0	8.4	8.0	33	17.0	13.3	11.5	10.4	9.6
19	12.3	10.2	9.2	8.5	8.1	34	17.3	13.6	11.7	10.5	9.7
20	12.7	10.4	9.3	8.7	8.2	35	17.7	13.8	11.8	10.7	9.9
21	13.0	10.7	9.5	8.8	8.3	36	18.0	14.0	12.0	10.8	10.0
22	13.3	10.9	9.7	8.9	8.4	37	18.3	14.2	12.2	10.9	10.1
23	13.7	11.1	9.8	9.1	8.5	38	18.7	14.4	12.3	11.1	10.2
24	14.0	11.3	10.0	9.2	8.6	39	19.0	14.7	12.5	11.2	10.3
25	14.3	11.6	10.2	9.3	8.8	40	19.3	14.9	12.7	11.3	10.4
26	14.7	11.8	10.3	9.5	8.9	41	19.7	15.1	12.8	11.5	10.5
27	15.0	12.0	10.5	9.6	9.0	42	20.0	15.3	13.0	11.6	10.6
28	15.3	12.2	10.7	9.7	9.1	43	20.3	15.6	13.2	11.7	10.7
29	15.7	12.5	10.8	9.9	9.2	44	20.7	15.8	13.3	11.9	10.8
30	16.0	12.7	11.0	10.0	9.3	44	21.0	16.0	13.5	12.0	11.0
31	16.3	12.9	11.2	10.1	9.4	46	21.3	16.1	13.7	12.1	11.1
32	16.7	13.1	11.3	10.3	9.5						

Material	1:1	1:2	1:3	1:4	1:5
Cement	540	333	250	200	167
Sand	500	666	750	800	833

cloth, the cloth to be kept away from them by means of a wire screen; or they may be stored in a moist box or closet.

25. Care should be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point reduces tne area and tends to increase the penetration.

26. The determination of the time of setting is only approximate, being materially affected by the temperature of the mixing water, the temperature and humidity of the air during the test, the percentage of water used, and the amount of molding the paste receives.

Standard Sand.

27. For the present, the Committee recommends the natural sand from Ottawa, Ill., screened to pass a sieve having 20 meshes per linear inch and retained on a sieve having 30 meshes per linear inch; the wires to have diameters of 0.0165 and 0.0112 in., respectively, i. e., half the width of the opening in each case. Sand having passed the No. 20 sieve shall be considered standard when not more than 1 per cent passes a No. 30 sieve after one minute continuous sifting of a 500-gram sample.

28. The Sandusky Portland Cement Company, of Sandusky, Ohio, has agreed to undertake the preparation of this sand and to furnish it at a price only sufficient to cover the actual cost of preparation.

Form of Briquette.

29. While the form of the briquette recommended by a former Committee of the Society is not wholly satisfactory, this Committee is not prepared to suggest any change, other than rounding off the corners by curves of ½-in. radius.

Molds.

30. The molds should be made of brass, bronze or some equally non-corrodible material, having sufficient metal in the sides to prevent spreading during molding.

31. Gang molds, which permit molding a number of briquettes at one time, are preferred by many to single molds; since the greater quantity of mortar that can be mixed tends to produce greater uniformity in the results. The type shown in Fig. 4 is recommended.

32. The molds should be wiped with an oily cloth before using.

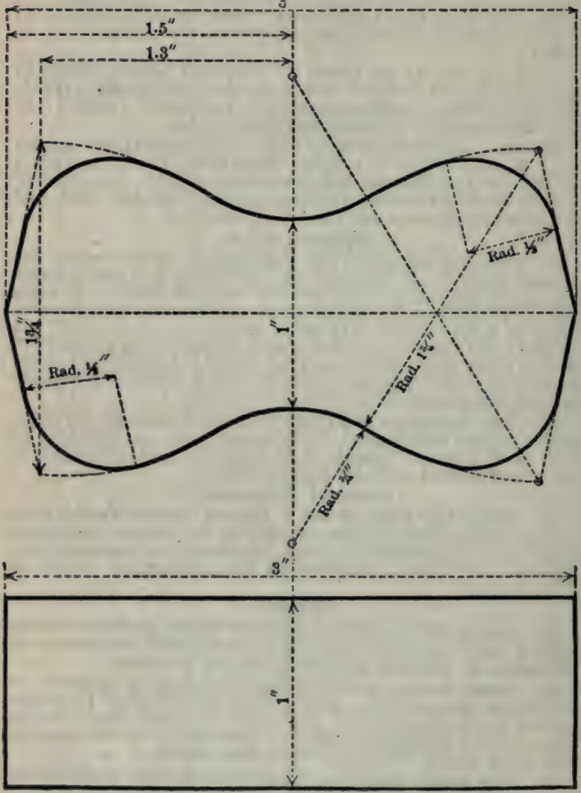


Fig. 3.

Mixing.

33. All proportions should be stated by weight; the quantity of water to be used should be stated as a percentage of the dry material.

34. The metric system is recommended because of the convenient relation of the gram and the cubic centimeter.

35. The temperature of the room and the mixing water should be as near 21° C. (70° F.) as it is practicable to maintain it.

36. The sand and cement should be thoroughly mixed dry. The mixing should be done on some non-absorbing surface, preferably plate glass. If the mixing must be done on an absorbing surface it should be thoroughly dampened prior to use.

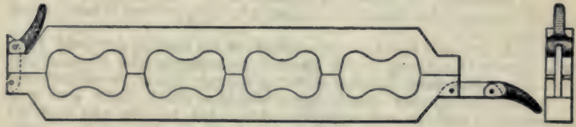


Fig. 4.

37. The quantity of material to be mixed at one time depends on the number of test pieces to be made; about 1,000 gr. (35.28 oz.) makes a convenient quantity to mix, especially by hand methods.

38. **Method.** The material is weighed and placed on the mixing table, and a crater formed in the center, into which the proper percentage of clean water is poured; the material on the outer edge is turned into the crater by the aid of a trowel. As soon as the water has been absorbed, which should not require more than one minute; the operation is completed by vigorously kneading with the hands for an additional 1½ minutes, the process being similar to that used in kneading dough. A sand-glass affords a convenient guide for the time of kneading. During the operation of mixing, the hands should be protected by gloves, preferably of rubber.

Molding.

39. Having worked the paste or mortar to the proper consistency, it is at once placed in the molds by hand.

40. **Method:** The molds should be filled at once, the material pressed in firmly with the fingers and smoothed off with a trowel without ramming; the material should be heaped up on the upper surface of the mold, and, in smoothing off, the trowel should be drawn over the mold in such a manner as to exert a moderate pressure on the excess material. The mold should be turned over and the operation repeated.

44. A check upon the uniformity of the mixing and molding is afforded by weighing the briquettes just prior to immersion, or upon removal from the moist closet. Briquettes which vary in weight more than 3 per cent from the average should not be tested.

Storage of the Test Pieces.

42. During the first 24 hours after molding, the test pieces should be kept in moist air to prevent them from drying out.

43. A moist closet or chamber is so easily devised that the use of the damp cloth should be abandoned if possible. Covering the test pieces with a damp cloth is objectionable, as commonly used, because the cloth may dry out unequally, and in consequence the test pieces are not all maintained under the same condition. Where a moist closet is not available, a cloth may be used and kept uniformly wet by immersing the ends in water. It should be kept from direct contact with the test pieces by means of a wire screen or some similar arrangement.

44. A moist closet consists of a soapstone or slate box, or a metal-lined wooden box—the metal lining being covered with felt and this felt kept wet. The bottom of the box is so constructed as to hold water, and the sides are provided with cleats for holding glass shelves on which to place the briquettes. Care should be taken to keep the air in the closet uniformly moist.

45. After 24 hours in moist air, the test pieces for longer periods of time should be immersed in water maintained as near 21° C. (70° F.) as practicable; they may be stored in tanks or pans, which should be of non-corrodible material.

Tensile Strength.

46. The tests may be made on any standard machine. A solid metal clip, as shown in the figure, is recommended.

This clip is to be used without cushioning at the points of contact with the test specimen. The bearing at each point of contact should be ¼ in. wide, and the distance between the center of contact on the same clip should be 1¼ in.

47. Test pieces should be broken as soon as they are removed from the water. Care should be observed in centering the briquettes in the testing machine, as cross-strains, produced by improper centering, tend to lower the breaking strength. The load should not be applied too suddenly, as it may produce vibration, the shock from which often breaks the briquette before the ultimate strength is reached. Care must be taken that the clips and the sides of the briquette be clean and free from grains of sand or dirt, which would prevent a good bearing. The load should be applied at the rate of 600 lb. per minute. The average of the briquettes of each sample tested should be taken as the test, excluding any results which are manifestly faulty.

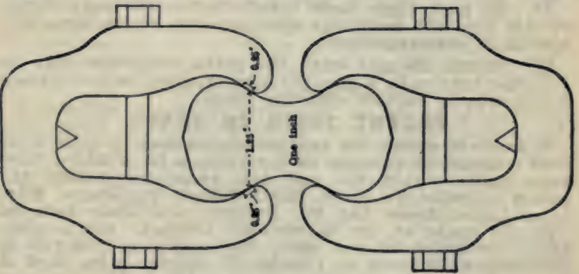


Fig. 5.

Constancy of Volume.

48. **Methods:** Tests for constancy of volume are divided into two classes: (1) normal tests, or those made in either air or water maintained at about 21° C. (70° F.), and (2) accelerated tests, or those made in air, steam or water at a temperature of 45° C. (115° F.) and upward. The test pieces should be allowed to remain 24 hours in moist air before immersion in water or steam, or preservation in air.

49. For these tests, pats about 7½ cm. (2.95 in.) in diameter, 1¼ cm. (0.49 in.) thick at the center, and tapering to a thin edge, should be made, upon a clean glass plate [about 10 cm. (3.94 in.) square], from cement paste of normal consistency.

50. **Normal Test:** A pat is immersed in water maintained as near 21° C. (70° F.)) as possible for 28 days, and observed at intervals. A similar pat is maintained in air at ordinary temperature and observed at intervals.

51. **Accelerated Test:** A pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel.

52. To pass these tests satisfactorily, the pats should remain firm and hard, and show no signs of cracking, distortion or disintegration.

53. Should the pat leave the plate, distortion may be detected best with a straight-edge applied to the surface which was in contact with the plate.

RECENT TESTS ON BEAMS.

In order to enable the readers of this book to form their own conclusions relative to the various tests which have been made within the last few years we publish the tables compiled by Profs. Hatt, Talbot, Turneaure, Marburg, Lanza, Howe and Mr. Harding, also those tests on columns made at the Watertown Arsenal. For a complete discussion of the same the reader is referred to Reinforced Concrete by Charles F. Marsh. Also Buel & Hill. These tables appear on pages 136 to 151 inclusive.

TABLE OF LINEAR MEASURES.

(M. M.)	(C. M.)	
10 millimeters	=1 centimeter	= 0.3937 in.
10 centimeters	=1 decimeter	= 3.937 in.
10 decimeters	=1 meter	= 39.37 in.
10 meters	=1 dekameter	=393.37 in.
10 dekameters	=1 hectometer	=328.00 ft. 1 in.
10 hectometers	=1 kilometer (k. m.)	= 0.62137 miles.
10 kilometers	=1 myriameter	= 6.2137 miles.

The meter is used in general, the centimeter or millimeter in reckoning short distances, and the kilometer for long distances.

A centimeter is about ⅜ of an inch.

A meter is about 3 ft. 3⅜ in.

A kilometer is about 200 rods, or ⅝ of a mile.

Table of Weights.

10 milligrams (mg.) = 1 centigram = 0.1543 troy gr.
10 centigrams = 1 decigram = 1.543 troy gr.
10 decigrams = 1 gram (g.) = 15.432 troy gr.
10 grams = 1 dekagram = 0.3527 avoir.oz.
10 dekagrams = 1 hectogram = 3.5274 avoir. lb
10 hectograms = 1 kilogram (k.) = 2.204 avoir. lb
10 kilograms = 1 myriagram = 22.046 avoir. lb
10 myriagrams = 1 quintal = 220.46 avoir. lb
10 quintals = 1 tonneau (t.) = 2204.6 avoir. lb

1 kilogram per kilometer = 0.67195 lb. per 1000 ft.
1 lb. per 1000 ft. = 1.4882 kilograms per kilometer.
1 kilogram per sq. kilometer = 1423 lb. per sq. in.
1 lb. per sq. in. = .000743 kilograms per sq. millimeter.

Tables on Sizes and Properties.

The tables beginning on page 152 are placed in the back of the book for quick reference, as we believe the values given are those most frequently used and consequently should be placed where they can be most conveniently found.

1. Bearing power of soils.

Tests Carried out by Professor Talbot at Illinois University, 1904.
Concrete mixed Moderately Wet in the Proportion of 1:3:6, having Compressive Strength of 2,030 Pounds per Square Inch.

Loads Applied at two points ⅓ the length of the span from either support.

*The Kahn bars, owing to their formation, had their wings bent up inside the central third of the length of the span, and consequently did not offer their full resistance at these points.

No. of beam	Age in days	Amount and kind of reinforcement	Per cent of metal	No. of bars bent up	Length of central portion of span where metal has its full section, no bars being bent up	Size of beam	Depth to center of reinforcement	Span of beam	Elastic limit of reinforcement
					Inches	Inches	Ins	Feet	
1	61	3 ¾ in. Thacher	0.83	Nil	Total span	12x13½	12	14	35000
2	64	5 ½ in. Johnson	0.69	"	" "	"	12	14	33000 to 60000
3	63	3 ½ in. Johnson	0.42	2	66	"	12	14	55000 to 60000
*4	63	5 ½ in. Kahn	1.39	Wings bent up	42	"	12	14	33000 to 35000

*5	65	3 ½ in. Kahn	0.83	"	42	"	12	14	
6	63	7 ½ in. Johnson	0.97	3	66	"	12	14	55000 to 60000
7	63	3 ½ in. Johnson	0.42	Nil	Total span	"	12	14	55000 to 60000
8	64	Nil	....	......	......	"	..	14	......
9	62	3 ½ in. Ransome	0.52	8 stirrups	Total span	"	12	14	Not found, but about 85000 according to Prof. Talbot
10	62	3 ¾ in. Thacher	0.83	2	66	"	12	14	35000
11	65	Nil	....	......	......	"	..	14	......
*12	65	3 ½ in. Kahn	0.83	Wings bent up	42	"	12	14	33000 to 35000
13	63	7 ½ in. Johnson	0.97	4	66	"	12	14	55000 to 60000
*14	65	4 ½ in. Kahn	1.11	Wings bent up	42	"	12	14	33000 to 35000
15	64	3 ¾ in. Thacher	0.83	2	66	"	12	14	35000
16	60	3 ½ in. plain square	0.52	2	66	"	12	14	33000 to 35000
17	60	3 ½ in. plain square	0.52	2	66	"	12	14	33000 to 35000
18	64	Nil	....	......	......	"	..	14	......
19	60	3 ½ in. plain round	0.41	2	66	"	12	14	33000 to 35000
20	61	5 ½ in. Johnson	0.69	3	66	"	12	14	55000 to 60000
21	61	3 ½ in. plain round	0.41	2	66	"	12	14	33000 to 35000
*22	63	3 ¾ in. Kahn	1.67	Wings bent up	36	"	12	14	33000 to 35000
23	61	Nil	....	......	......	"	..	8.5	......
24	61	Nil	....	......	......	"	..	5	......
25	64	Nil	....	......	......	"	..	5	......
26	62	Nil	....	......	......	"	..	10.67	......
27	63	4 ¾ in. plain square	1.56	2	66	"	12	14	33000 to 35000
28	61	6 ¾ in. Johnson	1.52	4	66	"	12	14	55000 to 60000
29	59	6 ½ in. Johnson	1.48	2	66	12x 8	6½	10.67	55000 to 60000
30	62	Nil	....	......	......	12x13½	..	10.67	......
31	62	Nil	....	......	......	12x13½	..	8.5	......

PROFESSOR LANZA'S TESTS OF BEAMS.

No. of Beam	Age in Days	Kind of Rod	No. of Rods	Size of Rods. Inches	Percentage of Reinforcement $\frac{w}{bh}$x100	Method of Loading	$\frac{M}{bh^2}$
1	40	None	....	....	None	Center	54
2	40	Ransome	1	¼	0.07	"	74
3	39	"	1	½	0.24	At third points	288
4	38	"	1	¾	0.69	Center	560
5	50	"	1	⅞	0.93	"	603
6	50	"	1	1	1.22	"	643
7	41	"	1	1¼	1.91	"	526
8	41	"	2	1	2.45	"	761
9	42	"	2	1¼	3.80	"	944
10	42	"	2	1¼	3.80	"	854

11	45	"	2	1¼	3.80	"	945
12	30	"	2	1¼	3.80	At third points	660
13	31	"	2	1¼	3.80	" "	790
14	30	"	2	1¼	3.80	" "	660
15	58	Plain	1	1	1.22	" "	425
16	49	Ransome	1	1	1.22	" "	456
17	43	Plain	2	¾	1.38	" "	441
18	40	Ransome	2	¾	1.38	" "	521
19	35	Plain	4	½	1.22	" "	450
20	33	Ransome	4	½	1.22	" "	516
21	57	Plain	1	¼	0.07	" "	351
22	54	Ransome	2	⅞	1.87	" "	607
23	57	Plain	2	⅞	1.87	" "	554
24	47	Ransome	4	⅝	1.91	" "	528
25	50	Plain	4	⅝	1.91	" "	425
26	40	Ransome	2	¾	1.38	" "	671
27	49	"	1	1	1.22	" "	600

The concrete was 1:3:4 of trap rock to pass 1 inch screen. The beams were 8 inches wide, 12 inches deep and 11 feet span. The reinforcement was 10¼ inches from top.

All beams except Nos. 1, 2, 3, 4, 19, 20, 21 and 22 failed by a longitudinal shearing crack at or a little above the reinforcement and by a crack extending diagonally (often at about 45° to the horizontal) towards the center and joining the top of the beam at or near the load.

Beams Nos. 1, 2, and 3 failed by a vertical crack near the center.

Beam No. 4 crushed at top.

" No. 19 failed by a vertical crack about 18 inches from center.

" No. 20 failed by longitudinal shear alone.

" No. 21 failed by vertical crack at one of loads and rod pulled through (concrete was insufficiently packed in making).

" No. 22 failed by longitudinal shear (cracked in handling 22 inches from center).

PROFESSOR HATT'S TESTS ON CONCRETE BEAMS.

Proportion of Ingredients of Concrete	Nature of Piece		Age when Tested. Days	Condition		First Crack		Failure	
	Reinforcement Per cent.	Distance of Reinforcement from Underside Inches		Original	After Test	$\frac{M}{bh2}$	Deflexion in terms of span 1 over	$\frac{M}{bh2}$	Deflexion in terms of span 1 over
1:2:4 Stones	None		28	Normal	Crack 4 in. from center, weight 480 lbs.			94	26666
"	"		28	"	Crack at center, weight 485 lb.			90	5517
"	1	2	25	"	Crack 2 in. from center.	347	571	382	491
"	"	"	28	"	Crack at center.	347	588	434	430

"	2	"	25	"	"	400	734	712	288
"	"	"	27	Rather Wet.	"	451	609	712	288
"	1	1	25	Quivery.		870	580	883	552
"	"	"	23	"	"	382	533	372	452
"	2	"	27	Very wet.	Crack, 6 in. from center.	570	460	612	320
"	"	"	25	Rather dry.	Cracks 6 in. from center.	510	506	602	384
"	1	1½	30	Quivery.	Two cracks 2 in. each side center.	240	920	387	454
"	"	"	30	Normal.	Cracks 3 in. from center.	327	580	381	470
"	None		7	Rather dry.	Tested at ½ span.			133	10000
"	"		8	Normal.	Weight 480 lb.			60	4444
"	1	2	7	Rather dry.	Cracks 4 in. from center, weight 500 lb.	295	500	417	520
"	"	"	9	Normal.	Cracks at center.	243	792	382	286
1:2:5 Cinder	2	1	17	Normal.	Cracks 3 in. from center. Failure later in compression.	255	300	268	278
"	"	"	17	Too dry.	Cracks 4 in. from center.	102	1177	118	909
"	None		14	Normal.	Crack at center.			23	2500
"	"		11	"	Tested at ½ span.			43	4210
"	"		11	"	" "			43	6154
1:5 Gravel	3	1	6	"	Failed suddenly by horizontal shearing along reinforcement at end of beam.	510	645	587	500

Prof. Marburg's Tests of Beams. *h* is Distance from Top of Beam to Center of Rods, which were Placed 1 Inch from Bottom.

No,	Reinforcement	Span Feet	Percentage of Metal to total Cross Section	Average Limit of Elasticity of Rods Pounds per sq. in.	$\frac{M}{bh^2}$ At first Visible Crack	$\frac{M}{bh^2}$ At Failure	Deflexions in terms of the span 1 over	
							At first Crack	At Failure
1	Plain Square	5	1.17	37000	Not observed	402	Not observed	366
2	" "	5	1.17	37000	"	354	"	404
3	" "	5	1.17	37000	"	446	"	356
4	" "	8	1.17	37000	"	488	"	248
5	" "	8	1.17	37000	335	427	341	214
6	" "	8	1.17	37000	335 to 366	412	341 to 292	205
7	Johnson Bar	5	0.84	63000	361	432	426	323
8	" "	5	0.84	63000	380 to 402	456	455 to 417	335

9	" "	5	0.84	63000	247 to 266	391	807 to 709	358
10	" "	5	0.84	63000	380 to 402	408	407 to 371	371
11	" "	8	0.84	63000	244 to 274	554	640 to 532	150
12	" "	8	0.84	63000	366	585	285	194
13	Ransome Bar	5	1.19	52000	361 to 380	396	421 to 368	338
4	" "	5	1.19	52000	340 to 323	419	579 to 511	306
15	" "	5	1.19	52000	285	342	577	359
16	" "	8	1.19	52000	335	451	327	193
17	" "	8	1.19	52000	366	534	341	154
18	Thacher Bar	5	0.92	29500	247	304	676	317
19	" "	5	0.92	29500	247	410	781	263
20	" "	5	0.92	29500	247	380	780	304
21	" "	8	0.92	29500	305 to 335	375	434 to 370	244
22	" "	8	0.92	29500	335	435	382	225
23	" "	8	0.92	29500	305 to 335	390	405 to 347	189

DETAILS OF TESTS MADE BY J T. HARDING ON SHEAR IN BEAMS.

No. of Beam	Description of Reinforcement	Percent. of Reinforcement at Center of span	Max. Tension in Steel from Deformation. Lbs. per sq. in.	Max. Compression in Concrete from Deformation. Lbs. sq. in.	Maximum End Shear. Lbs.	Max. Vertical Shear. lbs. sq. in.	$\frac{M}{bh_2}$	Max. Variations in ult. Bending Moment for the 3 Beams each set	Description of Failure
								Per cent	
1	Ransome	75	31500	1155	22325	149	249	40	All beams showed quick diagonal failure, and one showed further a horizontal shearing along the bars.
2	Ransome	75	60300	2700	34875	233	392	2½	All beams showed a slow diagonal failure.
3	Ransome	75	61200	2090	43225	277	444.5	16	Two beams showed a quick diagonal failure, one developing a crack along the bars. The other beam failed in tension with slow compression failure in concrete at ultimate load.

4	Kahn	68	36900	1365	28525	162	232	1½	All beams failed in tension, showing slight compression at ultimate load.
5	Johnson	72	59700	2140	47875	272	412	12	One beam showed slow diagonal failure and the other two a slow failure in compression.
6	Johnson	72	42600	1560	32925	192	202	33	All beams showed a quick diagonal failure.
7	Plain round	75	37200	1540	25810	162	254	42	All beams showed a quick diagonal failure.
8	Plain round	75	40800	1610	31640	198	312	5	All beams showed a slow tension failure.
9	Johnson	75	36600	1560	35860	183	261	20	All beams showed a quick diagonal failure.
10	Johnson	75	57300	2590	55640	300	407.5	6	All beams showed a quick diagonal failure.

ALL BEAMS LOADED AT ⅓RD POINTS EXCEPT WHERE OTHERWISE STATED.

DATA ON BEAMS.

Beam No.	Kind of Concrete	Amount of Reinforcement	Per cent of Reinforcement	Age at Test Days	Method of Applying Load	Method of Failure
5	1 : 3 : 6	4 ½-in. Round	0.98	69	Continuous	Tension in steel
11	"	" "	0.98	65	"	" "
13	"	" "	0.98	62	Progressively applied and released	" "
14	"	" "	0.98	63	At two points, 7½ ft. apart, continuous	Diagonal tension
15	"	" "	0.98	63	" "	" "
16	"	" "	0.98	63	8,000 pounds retained 28 hours	Tension in steel
17	"	" "	0.98	65	9.000 pounds repeated 10 times	Tension in steel followed by diagonal tension
18	"	" "	0.98	72	At two points 7½ feet apart continuous	Diagonal tension

19	"	" "	0.98	63	6,000 pounds repeated 8 times 10,000 pounds repeated 6 times	Tension in steel
20	"	" "	0.98	64	Progressively applied and released	Diagonal tension
21	"	" "	0.98	62	At middle, continuous	Tension in steel
22	"	" "	0.98	63	9,000 pounds retained 20 hours	" "
23	"	" "	0.98	62	13 hours' rest after 6,000 pounds 9,000 pounds repeated twice	" "
24	"	4 ¾-in. Round	2.21	63	Progressively applied and released	Diagonal tension
26	"	4 ½-in. Round	0.98	64	5,000 pounds retained 25 hours	Tension in steel
27	"	3 ½-in. Round	0.74	68	Continuous rest after load of 6,000 pounds	" "
28	"	4 ¾-in. Round	2.21	60	Progressively applied and released	Diagonal tension
29	"	" "	2.21	62	12,000 pounds repeated 15 times	Diagonal cracks followed by compression
30	"	4 ½-in. Round	0.98	62	At middle, continuous	Tension in steel
31	"	" "	0.98	62	15 hours' rest after 8,000 pounds	" "
33	"	3 ¾-in. Round	1.66	60	Continuous	Diagonal tension
34	"	" "	1.66	60	"	" "
35	"	3 ½-in. Round 2 ¾-in. Round	1.84	60	"	Tension in steel
36	"	3 ½-in. Round	0.74	62	Continuous. Load of 6,000 pounds retained 24 hours	" "
37	"	5 ½-in. Round	1.24	59	Continuous	" "

ALL BEAMS LOADED AT ⅓RD POINTS EXCEPT WHERE OTHERWISE STATED.

DATA ON BEAMS—*Continued.*

Beam No.		Kind of Concrete	Amount of Reinforcement	Per ct. of Re-inforcem'nt	Age at Test Days	Method of Applying Load	Method of Failure
38		1 : 3 : 6	2 ¾-in. Round 2 ½-in. Round	1.60	57	Continuous	Diagonal tension
39	Abnormal	Poorly mixed	4 ½-in. Round	0.98	61	"	" "
40		"	" "	0.98	61	"	" "
41		Lean concrete at bottom	" "	0.98	61	"	" "
42		"	" "	0.98	62	"	" "
43		Plane of set one inch from bottom	" "	0.98	61	"	Tension in steel
44		Plane of set 5½ inches from bottom	" "	0.98	61	"	Diagonal tension

45	1 : 3 : 6	3 ½ in. Round 2 ¾-in. Round	1.84	61	“	“ “
46	“	5 ¾-in. Round	2.76	61	“	Compression in concrete
47	“	4 ½-in. Round	0.98	60	At eight points, continuous	Tension in steel
48	“	“ “	0.98	64	Continuous	“ “
49	“	2 ¾-in. Round	1.10	60	“	Bond
50	“	4 ½-in. Round	0.98	387	Continuous; loaded up to 2000 pounds at age of 60 days, and observations made on effect of rest until age of 387 days, when loading was continued to failure	Tension in steel
51	“	3 ¾-in. Round	1.66	63	Continuous	Bond
52	“	“ “	1.66	60	“	“
53	“	2 ¾-in. Round	1.10	61	“	“
54	“	4 ½-in. Round	0.98	63	Continuous at middle	Tension in steel
55	“	3 ¾-in. Round	1.66	59	Continuous	Bond
56	“	2 ¾-in. Round	1.10	59	“	“
57	“	“ “	1.10	59	“	“
58	1 : 2 : 4	4 ½-in. Round	0.98	59	“	Tension in steel
59	“	“ “	0.98	59	“	“ “
60	1 : 3 : 6	2 ¾-in. Round	1.10	59	Continuous; two points 7½ feet apart	Bond
61	“	3 ¾-in. Round	1.66	59	Continuous	Bond
62	“	2 ¾-in. Round	1.10	59	“	“
63	“	“ “	1.10	58	“	Tension in steel
67	“	“ “	1.10	57	“	Bond

Beams Nos. 64, 38 and 66 were of plain concrete. All reinforcements of 0.98 per cent are considered as 1 per cent in discussion on tests.

TABULATED RESULTS OF PROF. TURNEAURE'S EXPERIMENTS ON PLAIN AND REINFORCED CONCRETE BEAMS.

No. of Beam	Kind of Rod	Elastic Limit of Rods	Size of Rods in.	No. of Rods	Method of Reinforcing	Percent of Reinforcement
1 to 4	None	......	..	..	....	....
5 to 8	Plain round	75000	⅜	4	Straight	1.07
9 to 12	" "	75000	½	2	"	0.97
13 to 16	" "	75000	⅜	4	2 straight and 2 bent up	1.07
17 to 20	" "	75000	⅜	4	All straight, with stirrups	1.07
21 to 24	" "	75000	⅜	4	2 straight, 2 bent, and stirrups	1.07
25 to 28	Johnson	59000	½	2	Straight	0.89
29 to 32	Ransome	73000	7-16	2	"	0.98
33 to 36	Thacher	45000	½	2	"	0.97
37 to 40	Plain round	75000	⅜	4	All straight, with stirrups	1.07

TWO EQUAL LOADS APPLIED SYMMETRICALLY ON EACH SIDE OF THE CENTER OF BEAM.

No. of Beam	Age in Days	Span Feet	No. of Bars	Size of Bars. Inches	Percentage of Reinforcement $\frac{w}{bh} \times 100$	Depth of Beam d	Distance of Reinforcement from top h	Breadth of Beam	$\frac{M}{bh2}$
1	74	10	2	½	0.70	5	4¼	12	434
2	76	12	3	½	0.72	7	6¼	12	453
3	72	15	4	½	0.70	9½	8½	12	464
4	73	15	6	½	0.72	14	12¾	12	473
5	71	12	2	¾	0.57	10	8¾	12	340
6	71	15	3	¾	0.56	14½	13	12	300
7	60	15	3	¾	0.56	14½	13	12	314
8	115	15	3	¾	0.56	14½	13	12	325
9	29	15	3	¾	0.56	14½	13	12	304
10	29	15	3	¾	0.56	14½	13	12	341
11	78	18	4	¾	0.58	19	17¼	12	331
12	78	18	4	¾	0.58	19	17¼	12	321
13	70	17.75	4	¾	0.58	19	17¼	12	318
14	68	18	4	¾	0.58	19	17¼	12	280
15	77	17.5	4	¾	0.58	19	17¼	12	304
16	77	15	2	⅞	0.69	14	12¾	12	385
17	77	18	3	⅞	0.69	21	19¼	12	308
18	75	18	2	1	0.72	18	16¼	12	358

Beams 9 and 10 failed by compression at center. Beams 14 and 15, load applied and removed several times, failed by shearing. Beam 17 failed by shearing.

*Permissible Bearing Value (Across the Grain) of Bolts in Timber, per in. of Length.**—(Kidder.)

Diameter of Bolt in ins.	Yellow Pine	Oregon Pine	Spruce	White Pine	Oak
¾	375	300	225	187	450
⅞	437	350	262	220	525
1	500	400	300	250	600
1⅛	562	450	337	280	675
1¼	625	500	375	310	750
1⅜	687	550	412	345	825
1½	750	600	450	375	900
1¾	875	700	490	437	1000
2	1000	800	600	500	1200

*Based on unit stresses of 600 lbs. per sq. in. for oak, 500 for Southern yellow pine, 400 for Oregon pine, 300 for spruce, and 250 for white pine.

Maximum Permissible Tension, Shear, and Bending Moment (in in.-lb.) for Wrought-iron Bolts in Timber.

Diameter of Bolt in ins.	Tension, lbs.*	Single Shear, lbs.	Bending Moment, in.-lbs.	Diameter of Bolt in ins.	Tension, lbs.*	Single Shear, lbs.	Bending Moment, in.-lbs.
¾	6000	4420	931	1¾	35000	24050	11800
⅞	8400	6010	1479	2	45000	31416	17700
1	10860	7850	2210	2¼	60000	39760	25200
1⅛	13720	9940	3140	2½	74000	49080	34500
1¼	17700	12270	4310	2¾	92000	59400	45900
1⅜	21400	14480	5740	3	108000	70700	59600
1½	25740	17670	7460	3¼	130000	82950	75800

Unit stresses: Tension, 20.000 lbs., shear, 10 000 lbs., bending 22,500 lbs.

*To be used only in truss joints. Not safe for rods.

Thickness for Foundation Walls.—(Kidder.)

Height of Building	Dwellings, Hotels, Etc.		Warehouses	
	Brick, in.	Stone, in.	Brick, in.	Stone, in.
Two stories................	12 or 16	20	16	20
Three stories..............	16	20	20	24
Four stories...............	20	24	24	28
Five stories...............	24	28	24	28
Six stories................	28	32	28	32

*Permissible Bearing Value (End Compression) of Bolts in Timber, per in. of Length, and Distance from Center of Bolt to the Next Bolt.**—(Kidder.)

Diameter of bolt in in.	Yellow Pine		Oregon Pine or Oak		Spruce		White or Soft Pine	
	Bearing, lbs.	Distance, ins.	Bearing, lbs.	Distance, ins.	Bearing, lbs.	Distance, ins.	Bearing, lbs.	Distance, ins.
¾	1125	5	1012	4½	900	5	750	5
⅞	1310	6	1183	5	1050	5½	880	5½
1	1500	6	1350	5½	1200	6½	1000	6
1⅛	1690	7	1520	6	1350	7	1125	7
1¼	1870	7½	1690	6½	1500	7½	1250	8
1⅜	2060	8	1860	7½	1650	8	1375	9
1½	2250	9	2025	8	1800	9	1500	10
1¾	2625	10	2360	9	2100	10	1750	11
2	3000	11	2700	10	2400	12	2000	12
2¼	3375	12	3040	11	2700	13½	2250	13½
2½	3750	13	3375	12	3000	15	2500	15
2¾	4125	14	3710	13	3300	16½	2750	16½
3	4500	15	4050	14	3600	18	3000	18

*Based on a bearing resistance of 1500 lbs. per sq. in. for Southern yellow pine, 1350 lbs. for oak and Oregon pine, 1200 lbs. for spruce, and 1000 lbs. for white pine.

Decimal Equivalents for Fractions of an Inch.

1-32ds	1-64ths	Decimal	Fraction	1-32ds	1-64ths	Decimal	Fraction
	1	.015625			33	.515625	
1	2	.03125		17	34	.53125	
	3	.046875			35	.546875	
2	4	.0625	1-16	18	36	.5625	9-16
	5	.078125			37	.578125	
3	6	.09375		19	38	.59375	
	7	.109375			39	.609375	
4	8	.125	⅛	20	40	.625	⅝
	9	.140625			41	.640625	
5	10	.15625		21	42	.65625	
	11	.171875			43	.671875	
6	12	.1875	3-16	22	44	.6875	11-16
	13	.203125			45	.703125	
7	14	.21875		23	46	.71875	
	15	.234375			47	.734375	
8	16	.25	¼	24	48	.75	¾
	17	.265625			49	.765625	
9	18	.28125		25	50	.78125	
	19	.296875			51	.796875	
10	20	.3125	5-16	26	52	.8125	13-16
	21	.328125			53	.828125	
11	22	.34375		27	54	.84375	
	23	.359375			55	.859375	
12	24	.375	⅜	28	56	.875	⅞
	25	.390625			57	.890625	
13	26	.40625		29	58	.90625	
	27	.421875			59	.921875	
14	28	.4375	7-16	30	60	.9375	15-16
	29	.453125			61	.953125	
15	30	.46875		31	62	.96875	
	31	.484375			63	.984375	
16	32	.5	½	32	64	1.	1

Wire and Sheet Metal Gauges.—(Cambria Steel Co.)

In Decimals of an Inch.

Number of Gauge	Birmingham or Stubs Iron Wire Gauge	American or Brown & Sharpe Wire Gauge	United States Standard Gauge for Sheet and Plate Iron and Steel	Washburn & Moen Manufacturing Co. and John A. Roebling's Sons Co. Wire Gauge	Trenton Iron Co. Wire Gauge	American Screw Co. Screw Wire Gauge	British Imperial or English Legal Standard Wire Gauge
0000000	....	....	.5	.....	.....	.....	.500
000000	....	....	.46875	.4600	.....	.....	.464
00000	....	....	.4375	.4300	.450	.....	.432
0000	.454	.460000	.40625	.3938	.400	.....	.400
000	.425	.409642	.375	.3625	.360	.0315	.372
00	.380	.364796	.34375	.3310	.330	.0447	.348
0	.340	.324861	.3125	.3065	.305	.0578	.324
1	.300	.289297	.28125	.2830	.285	.0710	.300
2	.284	.257627	.265625	.2625	.265	.0842	.276
3	.259	.229423	.25	.2437	.245	.0973	.252
4	.238	.204309	.234375	.2253	.225	.1105	.232
5	.220	.181940	.21875	.2070	.205	.1236	.212
6	.203	.162023	.203125	.1920	.190	.1368	.192
7	.180	.144285	.1875	.1770	.175	.1500	.176
8	.165	.128490	.171875	.1620	.160	.1631	.160
9	.148	.114423	.15625	.1483	.145	.1763	.144
10	.134	.101497	.140625	.1350	.130	.1894	.128
11	.120	.090742	.125	.1205	.1175	.2026	.116
12	.109	.080808	.109375	.1055	.105	.2158	.104
13	.095	.071962	.09375	.0915	.0925	.2289	.092
14	.083	.064084	.078125	.0800	.0806	.2421	.080
15	.072	.057068	.0703125	.0720	.070	.2552	.072
16	.065	.050821	.0625	.0625	.061	.2684	.064
17	.058	.045257	.05625	.0540	.0525	.2816	.056
18	.049	.040303	.05	.0475	.045	.2947	.048
19	.042	.035890	.04375	.0410	.040	.3079	.040
20	.035	.031961	.0375	.0348	.035	.3210	.036
21	.032	.028462	.034375	.03175	.031	.3342	.032
22	.028	.025346	.03125	.0286	.028	.3474	.028

Wire and Sheet Metal Gauges.—Continued.

In Decimals of an Inch.

Number of Gauge	Birmingham or Stubs Iron Wire Gauge	American or Brown & Sharpe Wire Gauge	United States Standard Gauge for Sheet and Plate Iron and Steel	Washburn & Moen Manufacturing Co. and John A. Roebling's Sons Co. Wire Gauge	Trenton Iron Co. Wire Gauge	American Screw Co. Screw Wire Gauge	British Imperial or English Legal Standard Wire Gauge
23	.025	.022572	.028125	.0258	.025	.3605	.024
24	.022	.020101	.025	.0230	.0225	.3737	.022
25	.020	.017900	.021875	.0204	.020	.3868	.020
26	.018	.015941	.01875	.0181	.018	.4000	.018
27	.016	.014195	.0171875	.0173	.017	.4132	.0164
28	.014	.012641	.015625	.0162	.016	.4263	.0148
29	.013	.011257	.0140625	.0150	.015	.4395	.0136
30	.012	.010025	.0125	.0140	.014	.4526	.0124
31	.010	.008928	.0109375	.0132	.013	.4658	.0116
32	.009	.007950	.01015625	.0128	.012	.4790	.0108
33	.008	.007080	.009375	.0118	.011	.4921	.0100
34	.007	.006305	.00859375	.0104	.010	.5053	.0092
35	.005	.005615	.0078125	.0095	.0095	.5184	.0084
36	.004	.005000	.00703125	.0090	.009	.5316	.0076
37	....	.004453	.006640625	.0085	.0085	.5448	.0068
38	....	.003965	.00625	.0080	.008	.5579	.0060
39	....	.003531	....	.0075	.0075	.5711	.0052
40	....	.003144	....	.0070	.007	.5842	.0048

The United States Standard Gauge was legalized by Act of Congress March 3, 1893, as a standard gauge for sheet and plate iron and steel, and is used by the Custom House Department and by about forty-five sheet and tin-plate manufacturers.

Table of Pressures Corresponding to Given Heads of Water.—(Trautwine.)

Water at maximum density, 62.425 lb. per cu. ft. =1 gram per cu. ft. centimeter, corresponding to a temperature of 4° Centigrade=39.2° F.

Pressure in lb. per sq. in.= 0.433507 X head in ft.
" " " ft.=62.425 X " "

Head in ft.	Pressure		Head in ft.	Pressure		Head in ft.	Pressure	
	Lb. per sq. in.	Lb. per sq. ft.		Lb. per sq. in.	Lb. per sq. ft.		Lb. per sq. in.	Lb. per sq. ft.
1	0.4335	62.425	34	14.7392	2122.450	67	29.0450	4182.475
2	0.8670	124.850	35	15.1727	2184.875	68	29.4785	4244.900
3	1.3005	187.275	36	15.6063	2247.300	69	29.9120	4307.325
4	1.7340	249.700	37	16.0398	2309.725	70	30.3455	4369.750
5	2.1675	312.125	38	16.4733	2372.150	71	30.7790	4432.175
6	2.6010	374.550	39	16.9068	2434.575	72	31.2125	4494.600
7	3.0345	436.975	40	17.3403	2497.000	73	31.6460	4557.025
8	3.4681	499.400	41	17.7738	2559.425	74	32.0795	4619.450
9	3.9016	561.825	42	18.2073	2621.850	75	32.5130	4681.875
10	4.3351	624.250	43	18.6408	2684.275	76	32.9465	4744.300
11	4.7686	686.675	44	19.0743	2746.700	77	33.3800	4806.725
12	5.2021	749.100	45	19.5078	2809.125	78	33.8135	4869.150
13	5.6356	811.525	46	19.9413	2871.550	79	34.2471	4931.575
14	6.0691	873.950	47	20.3748	2933.975	80	34.6806	4994.000
15	6.5026	936.375	48	20.8083	2996.400	81	35.1141	5056.425
16	6.9361	998.800	49	21.2418	3058.825	82	35.5476	5118.850
17	7.3696	1061.225	50	21.6753	3121.250	83	35.9811	5181.275
18	7.8031	1123.650	51	22.1089	3183.675	84	36.4146	5243.700
19	8.2366	1186.075	52	22.5424	3246.100	85	36.8481	5306.125
20	8.6701	1248.500	53	22.9759	3308.525	86	37.2816	5368.550
21	9.1036	1310.925	54	23.4094	3370.950	87	37.7151	5430.975
22	9.5372	1313.350	55	23.8429	3433.375	88	38.1486	5493.400
23	9.9707	1435.775	56	24.2764	3495.800	89	38.5821	5555.825
24	10.4042	1498.200	57	24.7099	3558.225	90	39.0156	5618.250
25	10.8377	1560.625	58	25.1434	3620.650	91	39.4491	5680.675
26	11.2712	1623.050	59	25.5769	3683.075	92	39.8826	5743.100
27	11.7047	1685.475	60	26.0104	3745.500	93	40.3162	5805.525
28	12.1382	1747.900	67	26.4439	3807.925	94	40.7497	5867.950
29	12.5717	1810.323	62	26.8774	3870.350	95	41.1832	5930.375
30	13.0052	1872.750	63	27.3109	3932.775	96	41.6167	5992.800
31	13.4387	1935.175	64	27.7444	3995.200	97	42.0502	6055.225
32	13.8722	1997.600	65	28.1780	4057.625	98	42.4837	6117.650
33	14.3057	2060.025	66	28.6115	4120.050	99	42.9172	6180.075

Table of Pressures Corresponding to Given Heads of Water.—(Trautwine.)

Water at maximum density, 62.425 lb. per cu. ft.=1 gram per cu. ft. centimeter, corresponding to a temperature of 4° Centigrade=39.2° F.

Pressure in lb. per sq. in.= 0.433507 X head in ft.
" " " ft.=62.425 X " " .

Head in.	Pressure		Head in.	Pressure	
	Lb. per sq. in.	Lb. per sq. ft.		Lb. per sq. in.	Lb. per sq. ft.
1	0.036126	5.202083	7	0.252879	36.414583
2	0.072251	10.404167	8	0.289005	41.616667
3	0.108377	15.606250	9	0.325130	46.818750
4	0.144502	20.808333	10	0.361256	52.020833
5	0.180628	26.010417	11	0.397381	57.222917
6	0.216753	31.212500	12	0.433507	62.425000

Results of Tests Showing Effect of Sand on Strength of Mortars.

From "Annales des Ponts et Chaussees."

Size of Sand	Percentage of Water	Tensile Strength in Kilogrammes per Square Centimetre					
		3 Days	7 Days	28 Days	3 Months	1 Year	2 Years
1	15	1.97	3.83	6.56	8.79	10.73	12.14
2	17	1.29	3.87	7.49	10.40	11.35	13.14
3	22	1.00	2.50	5.24	9.27	11.11	11.24
4	27	0.77	2.22	4.90	6.90	8.32	10.36
5	33	0.39	1.94	4.17	6.74	8.21	9.06
Mixture of above Sand	22	1.45	3.29	7.39	10.49	13.17	14.16

Results of Experiments by Herr R. Dykerhoff on Effect of Sand on Strength of Mortars.

Proportions of Ingredients by Weight					Tensile Strength in Pounds per Square Inch			Weight of 5 Briquettes
Cement	Normal Sand	Rhine Sand	Ground Sand	Ground Marble	7 Days	28 Days	90 Days	
1	4	...	..	..	221	249	309	786
1	4	...	½	..	256	307	366	825
1	4	...	..	½	255	307	372	820
1	..	4½	..	..	...	...	362	805
1	..	4	..	..	...	...	426	827

Thickness of Enclosing Walls for Hotels, Office Buildings, Etc., Specified by the Chicago Building Ordinance.

No. of Stories	Basement	Stories											
		1	2	3	4	5	6	7	8	9	10	11	12
Basement	12	8											
and 2-story.	12	12	8										
Three story..	16	12	12	8									
Four story...	20	16	16	12	12								
Five story...	20	16	16	16	12	12							
Six story.....	20	20	16	16	16	12	12						
Seven story..	24	24	20	20	16	16	12	12					
Eight story..	24	24	24	20	20	16	16	12	12				
Nine story...	28	24	24	20	20	20	16	16	12	12			
Ten story....	28	24	24	24	20	20	20	16	16	12	12		
Eleven story.	28	28	24	24	24	20	20	20	16	16	12	12	
Twelve story	32	28	28	24	24	24	20	20	20	16	16	12	12

THICKNESS OF WALLS IN INCHES, FOR MERCANTILE BUILDINGS AND PUBLIC STABLES.—(*Kidder.*)

Height of Building		Stories							
		1	2	3	4	5	6	7	8
Two Stories	Boston	16	12						
	New York	12	12						
	Chicago	12	12						
	Minneapolis	12	12						
	St. Louis	18	13						
	Denver	13	13						
	San Francisco	17	13						
	New Orleans	13	13						
Three Stories	Boston	20	16	16					
	New York	16	16	12					
	Chicago	16	12	12					
	Minneapolis	16	12	12					
	St. Louis	18	18	13					
	Denver	17	17	13					
	San Francisco	17	17	13					
	New Orleans	13	13	13					
Four Stories	Boston	20	16	16	16				
	New York	16	16	16	12				
	Chicago	20	16	16	12				
	Minneapolis	16	16	12	12				
	St. Louis	22	18	18	13				
	Denver	21	17	17	13				
	San Francisco	17	17	17	13				
	New Orleans	18	18	13	13				

Five Stories	Boston	20	20	20	20	16			
	New York	20	16	16	16	16			
	Chicago	20	20	16	16	16			
	Minneapolis	20	16	16	12	12			
	St. Louis	22	22	18	18	13			
	Denver	21	21	17	17	13			
	San Francisco	21	17	17	17	13			
	New Orleans	18	18	18	13	13			
Six Stories	Boston	24	20	20	20	20	16		
	New York	24	20	20	20	16	16		
	Chicago	20	20	20	16	16	16		
	Minneapolis	20	20	16	16	16	12		
	St. Louis	26	22	22	18	18	13		
	Denver	26	21	21	17	17	13		
	San Francisco	21	21	17	17	17	13		
	New Orleans	22	18	18	18	13	13		
Seven Stories	Boston	24	20	20	20	20	20	16	
	New York	28	24	24	20	20	16	16	
	Chicago	20	20	20	20	16	16	16	
	Minneapolis	20	20	20	16	16	16	12	
	St. Louis	26	26	22	22	18	18	13	
	Denver	26	21	21	21	17	17	17	
	New Orleans	22	22	18	18	18	18	13	
Eight Stories	Boston	28	24	20	20	20	20	20	16
	New York	32	28	24	24	20	20	16	16
	Chicago	24	24	20	20	20	16	16	16
	Minneapolis	24	20	20	20	16	16	16	12
	St. Louis	30	26	26	22	22	18	18	13
	Denver	30	26	21	21	21	17	17	17
	New Orleans	22	22	22	18	18	18	13	13

THICKNESS OF WALLS IN INCHES, FOR MERCANTILE BUILDINGS AND PUBLIC STABLES.—(*Kidder.*)

Height of Building		Stories											
		1	2	3	4	5	6	7	8	9	10	11	12
Nine Stories	Boston	28	24	24	20	20	20	20	20	16			
	New York	32	32	28	24	24	20	20	16	16			
	Chicago	24	24	24	20	20	20	16	16	16			
	Minneapolis	24	24	20	20	20	16	16	16	12			
	St. Louis	30	30	26	26	22	22	18	18	13			
	Denver	30	26	26	21	21	21	17	17	17			
Ten Stories	Boston	28	28	24	24	20	20	20	20	20	16		
	New York	36	32	32	28	24	24	20	20	16	16		
	Chicago	28	28	24	24	24	20	20	20	16	16		
	Minneapolis	24	24	24	20	20	20	16	16	16	12		
	St. Louis	34	30	30	26	26	22	22	18	18	13		
	Denver	30	30	26	26	21	21	21	17	17	17		
Eleven Stories	Boston	36	32	32	28	28	24	20	20	20	20	16	
	New York	36	36	32	28	28	24	24	20	20	16	16	
	Chicago	28	28	24	24	24	20	20	20	16	16	16	
	St. Louis	34	34	30	30	26	26	22	22	18	18	13	
	Denver	30	30	26	26	26	21	21	21	17	17	17	
Twelve Stories	Boston	36	36	32	32	28	28	24	20	20	20	20	16
	New York	40	36	36	32	32	28	24	24	20	20	16	16
	Chicago	28	28	28	24	24	24	20	20	20	16	16	16
	St. Louis	34	34	34	30	30	26	26	22	22	18	18	13
	Denver	30	30	30	26	26	26	21	21	21	17	17	17

Safe Loads, in Tons, for Piles.—(*Kidder.*)

(Hammer Weighing 1 Ton.)

Penetration of Pile, in inches	Height of the Fall of the Hammer, in Feet												
	3	4	5	6	8	10	12	14	16	18	20	25	30
0.25	4.8	6.4	8.1	9.7	12.9	16.1	19.4	22.5	25.8	29.1	32.3		
0.50	4.0	5.3	6.7	8.0	10.7	13.3	16.1	18.7	21.3	24.0	26.6	33.3	
0.75	3.4	4.6	5.7	6.9	9.2	11.5	13.8	16.1	18.4	20.7	23.0	28.8	34.5
1.00	6.0	4.0	5.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	25.0	30.0
1.25		3.6	4.5	5.4	7.1	8.9	10.7	12.5	14.3	16.1	17.9	22.3	26.7
1.50		3.2	4.0	4.8	6.4	8.0	9.6	11.2	12.8	14.4	16.0	20.0	24.0
1.75			3.6	4.4	5.8	7.3	8.8	10.2	11.7	13.1	14.6	18.2	21.9
2.00			3.3	4.0	5.3	6.7	8.0	9.3	10.7	12.0	13.3	16.7	20.0
2.50				3.4	4.6	5.7	6.9	8.0	9.1	10.3	11.4	14.3	17.1
3.00				3.0	4.0	5.0	6.0	7.2	8.0	9.0	10.0	12.5	15.0
3.50					3.6	4.4	5.3	6.2	7.1	8.0	8.9	11.1	13.3
4.00					3.2	4.0	4.8	5.6	6.4	7.2	8.0	10.0	12.0
5.00						3.3	4.0	4.7	5.3	6.0	6.7	8.3	10.0
6.00							3.4	4.0	4.6	5.1	5.7	7.1	8.6

TENSILE STRENGTHS OF 3 TO 1 CEMENT MORTAR WITH NATURAL SANDS, ALL OF WHICH APPEARED TO BE OF THE SAME CHARACTER.

Percentage of Weight Retained on Sieves with Varying Number of Meshes per Lineal Inch								Percentage by Weight Passing Sieve with 100 Meshes per Lineal Inch	Tensile Strength Pounds per Square Inch
4	8	16	20	30	50	75	100		
0	26	21	16	11	9	8	7	2	700
0	29	29	13	10	12	5	1	1	447
0	22	21	11	17	20	8	1	1	370
0	13	15	10	19	33	6	1	1	341
0	9	10	6	11	45	15	2	1	332
0	13	15	7	8	38	15	4	1	309
0	0	0	0	1	6	69	23	2	246
0	0	0	0	0	0	0	6	94	200
0	0	0	2	3	15	45	30	5	189

TESTS OF SLAG CEMENT.

Authority	Place where Made	Percentage of Residue	Meshes of Sieve per Lineal Inch	Tensile Strength Pounds per Square Inch								
				Neat					1 to 3			
				Days					Days.			
				2	7	28	42	84	7	28	42	84
Pavin de Lafarge	Vitry-le-Francois	15	178		284	455		483	213	355		310
MM. Bergner and Guillerme*				256 to 356	398 to 484	568 to 710		710 to 854				
MM. Bergner and Guillerme	Cleveland....	19	127		350	436			240	334	360	396
	Cleveland....	21	127		404	485	502		216	366	396	427
	Newcastle ...	16	127		561	700			298	420	456	
	Cleveland....	12	127		483	611	645		289	405	430	450

*Good sample.

TESTS OF SLAG CEMENT—*Continued.*

Authority	Place where Made	Percentage of Residue	Meshes of Sieve per Lineal Inch	Compressive Strength Pounds per Square Inch								
				Neat					1 to 3			
				Days					Days			
				2	7	28	42	84	7	28	42	84
Pavin de Lafarge	Vitry-le-Francois	15	178		2560	3124		4972	1706	3413		3550
MM. Bergner and Guillerme*				2200 to 2620	3410 to 6110	4770 to 6100		4600 to 7350				
MM. Bergner and Guillerme	Cleveland....	19	127									
	Cleveland....	21	127									
	Newcastle ...	16	127									
	Cleveland....	12	127									

*Good sample.

Weights of Merchandise on Wooden Floors.—(Kidder.)

Material	Measurements		Weights		
	Floor space	Cubic feet	Gross	Per sq. ft.	Per cu. ft.
WOOL					
Bale East India	3.0	12.0	340	113	28
" Australia	5.8	26.0	385	66	15
" South America	7.0	34.0	1000	143	29
" Oregon	6.9	33.0	482	70	15
" California	7.5	33.0	550	73	17
Bag wool	5.0	30.0	200	40	7
Stack of scoured wool	....	....	....	....	5
WOOLEN GOODS					
Case flannels	5.5	12.7	220	40	17
" flannels, heavy	7.1	15.2	330	46	22
" dress goods	5.5	22.0	460	84	21
" cassimeres	10.5	28.0	550	52	20
" underwear	7.3	21.0	350	48	16
" blankets	10.3	35.0	450	44	13
" horse blankets	4.0	14.0	250	63	18
COTTON, ETC.					
Bale	8.1	44.2	515	64	12
" compressed	4.1	21.6	550	134	25
" American Cotton Co.	4.0	11.0	263	66	24
" Planters' Compressed Co.	2.3	7.2	254	110	35
" jute	2.4	9.9	300	125	30
" jute lashings	2.6	10.5	450	172	43
" manila	3.2	10.9	280	88	26
" hemp	8.7	34.7	700	81	20
" sisal	5.3	17.0	400	75	24
COTTON GOODS					
Bale unbleached jeans	4.0	12.5	300	72	24
Piece duck	1.1	2.3	75	68	33
Bale brown sheetings	3.6	10.1	235	65	23
Case bleached sheetings	4.8	11.4	330	69	30
" quilts	7.2	19.0	295	41	16
Bale print cloth	4.0	9.3	175	44	19
Case prints	4.5	13.4	420	93	31
Bale tickings	3.3	8.8	325	99	37
Skeins cotton yar.	....	....	....	....	11
Burlaps	....	....	130	....	30
Jute bagging	1.4	5.3	100	70	24

Weights of Merchandise on Wooden Floors.—Continued.

Material	Measurements		Weights		
	Floor space	Cubic feet	Gross	Per sq. ft	Per cu. ft.
RAGS IN BALES					
White linen	8.5	39.5	910	107	23
White cotton	9.2	40.0	715	78	18
Brown cotton	7.6	30.0	442	59	15
Paper shavings	7.5	34.0	507	68	15
Sacking	16.0	65.0	450	28	7
Woolen	7.5	30.0	600	80	20
Jute Butts	2.8	11.1	400	143	36
PAPER					
Calendered book	....	....	....	....	50
Super calendered book	....	....	....	....	69
News paper	....	....	....	....	38
Straw board	....	....	....	....	33
Leather board	....	....	....	....	59
Writing	....	....	....	....	64
Wrapping	....	....	....	....	10
Manila	....	....	....	....	37
GRAIN*					
Wheat in bags	4.2	4.2	165	39	39
" in bulk	....	....	....	....	44
" "	....	....	....	....	39
" " mean	....	....	....	....	41
Barrels flour on side	4.1	5.4	218	53	40
" " on end	3.1	7.1	218	70	31
Corn in bags	3.6	3.6	112	31	31
Cornmeal in barrels	3.7	5.9	218	59	37
Oats in bags	3.3	3.6	96	29	27
Bale of hay	5.0	20.0	284	57	14
Hay, Dederick compressed	1.75	5.25	125	72	24
Straw, " "	1.75	5.25	100	57	19
Tow, " "	1.75	5.25	150	86	29
Excelsior, Dederick compressed	1.75	5.25	100	57	19
Hay, loose	....	....	....	....	4

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* For pressure of grain in deep bins, see "Engineering News" of March 10, 1904, pp. 224 and 336; also of Dec. 15, 1904.

Weights of Merchandise on Wooden Floors.—Continued.

Material	Measurements		Weights		
	Floor space	Cubic feet	Gross	Per sq. ft.	Per cu. ft.
DYESTUFFS, ETC.					
Hogshead bleaching powder	11.8	39.2	1200	102	31
" soda ash	10.8	29.2	1800	167	62
Box indigo	3.0	9.0	385	128	43
" cutch	4.0	3.3	150	38	45
" sumac	1.6	4.1	160	100	39
Caustic soda in iron drum	4.3	6.8	600	140	88
Barrel starch	3.0	10.5	250	83	23
" pearl alum	3.0	10.5	350	117	33
Box extract logwood	1.06	.8	55	52	70
Barrel lime	3.6	4.5	225	63	50
" cement, American	3.8	5.5	325	86	59
" " English	3.8	5.5	400	105	73
" plaster	3.7	6.1	325	88	53
" resin	3.0	9.0	430	143	48
" lard oil	4.3	12.3	422	98	34
Rope	....	....	....	....	42
MISCELLANEOUS					
Box tin	2.7	0.5	139	99	278
" glass	....	....	....	....	60
Crate crockery	9.9	39.6	1600	162	40
Cask crockery	13.4	42.5	600	52	14
Bale leather	7.3	12.2	190	26	16
" goatskins	11.2	16.7	300	27	18
" raw hides	6.0	30.0	400	67	13
" " compressed	6.0	30.0	700	117	23
" sole leather	12.6	8.9	200	22	16
Pile sole leather	....	....	....	....	17
Barrel granulated sugar	3.0	7.5	317	106	42
" brown sugar	3.0	7.5	340	113	45
Cheese	....	....	....	....	30

TABLE SHOWING INCHES EXPRESSED IN DECIMALS OF A FOOT.

In.	0	1	2	3	4	5	6	7	8	9	10	11
0	Foot	.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167
1-23	.0026	.0859	.1693	.2526	.3359	.4193	.5026	.5859	.6693	.7526	.8359	.9193
1-16	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
3-32	.0078	.0911	.1745	.2578	.3411	.4245	.5078	.5911	.6745	.7578	.8411	.9245
1-8	.0104	.0938	.1771	.2604	.3438	.4271	.5104	.5938	.6771	.7604	.8438	.9271
5-32	.0130	.0964	.1797	.2630	.3464	.4297	.5130	.5964	.6797	.7630	.8464	.9297
3-16	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
7-32	.0182	.1016	.1849	.2682	.3516	.4349	.5182	.6016	.6849	.7682	.8516	.9349
1-4	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
9-32	.0234	.1068	.1901	.2734	.3568	.4401	.5234	.6068	.6901	.7734	.8568	.9401
5-16	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
11-32	.0286	.1120	.1953	.2786	.3620	.4453	.5286	.6120	.6953	.7786	.8620	.9453
3-8	.0313	.1146	.1979	.2813	.3646	.4479	.5313	.6146	.6979	.7813	.8646	.9479
13-32	.0339	.1172	.2005	.2839	.3672	.4505	.5339	.6172	.7005	.7839	.8672	.9505
7-16	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
15-32	.0391	.1224	.2057	.2891	.3724	.4557	.5391	.6224	.7057	.7891	.8724	.9557
1-2	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
17-32	.0443	.1276	.2109	.2943	.3776	.4609	.5443	.6276	.7109	.7943	.8776	.9609
9-16	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
19-32	.0495	.1328	.2161	.2995	.3828	.4661	.5495	.6328	.7161	.7995	.8828	.9661
5-8	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
21-32	.0547	.1380	.2214	.3047	.3880	.4714	.5547	.6380	.7214	.8047	.8880	.9714
11-16	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
23-32	.0599	.1432	.2266	.3099	.3932	.4766	.5599	.6432	.7266	.8099	.8932	.9766
3-4	.0625	.1458	.2292	.3125	.3958	.4792	.5625	6458	.7292	.8125	.8958	.9792
25-32	.0651	.1484	.2318	.3151	.3984	.4818	.5651	.6484	.7318	.8151	.8984	.9818

13-16	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
27-32	.0703	.1536	.2370	.3203	.4036	.4870	.5703	.6536	.7370	.8203	.9036	.9870
7-8	.0729	.1563	.2396	.3229	.4063	.4896	.5729	.6563	.7396	.8229	.9063	.9896
29-32	.0755	.1589	.2422	.3255	.4089	.4922	.5755	.6589	.7422	.8255	.9089	.9922
15-16	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948
31-32	.0807	.1641	.2474	.3307	.4141	.4974	.5807	.6641	.7474	.8307	.9141	.9974
	0	1	2	3	4	5	6	7	8	9	10	11

EFFECT OF FINENESS OF SAND UPON 1 TO 2 CEMENT MORTAR.

Size of Sand		Tensile Strength Pounds per Square Inch at the Following Times After Mixing				
Passed Meshes per Lineal inch	Retained Meshes per Lineal inch	After 7 Days	1 Month	3 Months	6 Months	1 Year
4	8	243	442	539	470	668
8	16	269	345	473	512	572
16	20	186	260	313	397	392
20	30	211	281	322	402	440
30	50	149	205	238	275	318
50	75	122	214	260	275	308
75	100	98	153	211	208	253
100	...	98	155	161	229	271

SIZE OF SHEETS OF EXPANDED METAL USED IN CONCRETE REINFORCEMENT.

Size of Mesh, short way of diamond, inches	Size of Strands, inches	Sec'l. area, per 12 in. width, sq. in.	Max. Stand. length, feet	Max. Stand. width, feet
6	⅜x3-16 bare	0.281		
6	¼x¼ "	0.250	8	16
6	¼x3-16 "	0.187	or	
6	¼x⅛ "	0.125	16	8
6	3-16x⅛ "	0.094		
6	⅛x⅛ "	0.062		
3	½x¼ "	1.000	8	12
3	½x3-16 "	0.750	8 or	11
3	⅜x3-16 "	0.562	12	8
3	¼x¼ "	0.500		
3	5-16x3-16 "	0.469		
3	¼x3-16 "	0.375		
3	5-16x⅛ "	0.312	8	16
3	3-16x3-16 "	0.281	or	
3	¼x⅛ "	0.250	16	8
3	3-16x⅛ "	0.187		
3	⅛x⅛ "	0.125		
3	¼x16 B.S.W.G. bare	0.125		
3	3-16x16 B.S.W.G. "	0.094		
1½	⅜x3-16 bare	1.124	8	8
1½	5-16x3-16 "	0.938		
1½	¼x3-16 "	0.750		
1½	¼x⅛ "	0.500	8	12
1½	3-16x⅛ "	0.375	or	
1½	⅛x⅛ "	0.250	16	8
1½	¼x16 B.S.W.G. bare	0.250		
1½	3-16x16 B.S.W.G "	0.188		
1½	⅛x16 B.S.W.G. "	0.125	8	12
1½	3-32x16 B.S.W. G. "	0.094		
1½	3-32x18 B.S.W.G. "	0.072		

COMPARATIVE TENSILE STRENGTHS IN POUNDS PER SQUARE INCH.

Freshly mixed	Left standing		Knocked up every 10 Minutes	
	After 1 hour	After 2 hours	After 1 hour	After 2 hours
185 226	186 233	180 231	165 223	170 236
	After 2½ hours	After 3 hours	After 2½ hours	After 3 hours
203	203	203	196	196
	After 3½ hours	After 4 hours	After 3½ hours	After 4 hours
158	146	161	163	168
	After 4½ hours	After 5 hours	After 4½ hours	After 5 hours
200	153	118	158	120

SAFE LOAD FOR MASONRY FOOTING COURSES.—(*Kidder.*)

Kind of Footing	R. in lb. per sq. in.*	Offset for a Pressure, in Tons per sq. ft., on the Bottom of the Course, of					
		0.5	1	2	3	5	10
Bluestone Flagging	2700	3.6	2.6	1.8	1.5	1.2	.8
Granite	1800	2.9	2.1	1.5	1.2	1.	.7
Limestone	1500	2.7	1.9	1.3	1.1	.9	.6
Sandstone	1200	2.6	1.8	1.3	1.0	.8	.5
Slate	5400	5.0	3.6	2.5	2.2	1.5	1.2
Best Hard Brick	1200	2.6	1.8	1.3	1.0	.8	.5
Concrete { 1 Portland 2 Sand 3 Pebbles }	150	0.8	0.6	0.4			
Concrete { 1 Rosendale 2 Sand 3 Pebbles }	80	0.6	0.4	0.3			

*Modulus of Rupture, values given by Prof. Baker in "Treatise on Masonry Construction."

Bearing Powers of Soils as Determined by Prof. Ira O. Baker, University of Illinois.

Kind of Material	Bearing Power in Tons per sq. ft.	
	Min.	Max.
Rock—the hardest—in thick layers, in native bed...	200	—
Rock Equal to best Ashlar masonry..................	25	30
Rock Equal to best brick masonry.........	15	20
Rock Equal to poor brick masonry....................	5	10
Clay on thick beds (always dry)......................	4	6
Clay on thick beds (moderately dry).................	2	4
Clay soft....................................	1	2
Gravel and coarse sand, well cemented..............	8	10
Sand, compact and well cemented....................	4	6
Sand, clean, dry..	2	4
Quicksand, Alluvial soils, etc........................	0.5	1

Values in lb. per sq. in. for Neat Cement Placed in Water

By Faija.

Time of Test after Molding	Tensile Strength
3 days......................	176
7 days......................	400, with a rise of 20 to 25 per cent of that of 3 days

Weights of Cement and Sand for Different Proportions.

	1:1	1:2	1:3	1:4	1:5
Cement	500	333	250	200	167
Sand	500	666	750	800	833

Table of Transmission of Power by Wire Ropes.

Showing necessary size and speed of wheels and rope to obtain any desired amount of power.—ROEBLING.

Diameter of Wheel in ft.	No. of Revolutions	Diameter of Rope	Horse Power	Diameter of Wheel in ft.	No. of Revolutions	Diameter of Rope	Horse Power
4	80	⅜	3.3	10	80	11-16	58.4
	100	⅜	4.1		100	11-16	73.
	120	⅜	5.		120	11-16	87.6
	140	⅜	5.8		140	11-16	102.2
5	80	7-16	6.9	11	80	11-16	75.5
	100	7-16	8.6		100	11-16	94.4
	120	7-16	10.3		120	11-16	113.3
	140	7-16	12.1		140	11-16	132.1
6	80	½	10.7	12	80	¾	99.3
	100	½	13.4		100	¾	124.1
	120	½	16.1		120	¾	148.9
	140	½	18.7		140	¾	173.7
7	80	9-16	16.9	13	80	¾	122.6
	100	9-16	21.1		100	¾	153.2
	120	9-16	25.3		120	¾	183.9
8	80	⅝	22.	14	80	⅞	148.
	100	⅝	27.5		100	⅞	185.
	120	⅝	33.		120	⅞	222.
9	80	⅝	41.5	15	80	⅞	217.
	100	⅝	51.9		100	⅞	259.
	120	⅝	62.2		120	⅞	300.

Transmission and Hoisting Ropes with Nineteen Wires to the Strand.—Iron.

Trade Number	Circumference in inches	Diameter	Weight per foot in lbs. of Rope, with Hemp Center	Breaking Strain in Tons of 2000 lbs.	Proper work-load in Tons of 2000 lbs.	Circumference of Hemp Rope of Equal Strength	Minimum Size of Drum or sh'v'e in ft.
1	6¾	2¼	7.80	74	15	15½	8
2	6	2	6.02	65	13	14½	7
3	5½	1¾	5.08	54	11	13	6½
4	5	1⅝	4.10	44	9	12	5
5	4⅜	1½	3.10	35	7	10¾	4½
6	4	1¼	2.44	27	5½	9½	4
7	3½	1⅛	1.95	20	4	8	3½
8	3⅛	1	1.50	16	3	7	3
9	2¾	⅞	1.14	11½	2½	6	2¾
10	2½	¾	0.83	8.64	1¾	5	2½
10¼	2	⅝	0.65	5.13	1¼	4¼	2
10½	1⅝	9-16	0.44	4.27	¾	4	1¾
10¾	1½	½	0.35	3.48	½	3½	1½

Values in lb. per sq. in. for Tensile Strength of Natural Cements.

From Baker's Masonry Construction.

Times before Testing	Neat	Cement to 2 Sand
24 hours—in water after setting................. ...	100	...
7 days—1 day in air, 6 days in water..................	200	125
28 days—1 day in air, 27 days in water................	300	200

Table of Strains Produced by Loads on Inclined Planes.

(Jones & Laughlin.)

Elevation in 100 feet	Strain in lbs. on Rope from a Load of 1 Ton	Elevation in 100 feet	Strain in lbs. on Rope from a Load of 1 Ton
ft. deg.		ft. deg.	
10 = 5½	112	90=42	1347
20 =11 1-5	404	100=45	1419
30=16¾	586	110=47¾	1487
40=21 5-6	754	120=50¼	1544
50=26⅓	905	130=52½	1592
60=31	1040	140=54½	1633
70=35	1156	150=56¼	1671
80=38⅔	1260	160=58	1703

Cut Steel Nails and Spikes.—Cambria Steel Co.

Sizes, Lengths, and Approximate Number per Pound.

Sizes	Length Inches	Common	Clinch	Finishing	Casing and Box	Fencing	Spikes
2d	1	740	400	1100			
3d	1¼	460	260	880			
4d	1½	280	180	530	420		
5d	1¾	210	125	350	300	100	
6d	2	160	100	300	210	80	
7d	2¼	120	80	210	180	60	
8d	2½	88	68	168	130	52	
9d	2¾	73	52	130	107	38	
10d	8	60	48	104	88	26	
12d	3¼	46	40	96	70	20	
16d	3½	33	34	86	52	18	17
20d	4	23	24	76	38	16	14
25d	4¼	20	...	....	...	...	
30d	4½	16½	...	....	30	...	11
40d	5	12	...	....	26	...	9
50d	5½	10	...	....	20	...	7½
60d	6	8	...	....	16	...	6
	6½	...	...	....	...	...	5½
	7	..	...	....	...	....	5

Cut Steel Nails and Spikes.—(Cambria Steel Co.)—Continued.

Sizes, Lengths, and Approximate Number per Pound.

Sizes	Length Inches	Barrel	Light Barrel	Slating	Sizes	Length Inches	Flat Grip. Fine	Edge Grip Fine
	⅝	750	...	...	...	¾	1462	
	¾	600	...	...	...	⅞	1300	
	⅞	500	...	...	2d	1	1100	960
2d	1	450	...	340	3d	1⅛	800	750
	1⅛	310	400	...	4d	1⅜	650	600
3d	1¼	280	304	280				
	1⅜	210	...	...	**Tobacco**		**Brads**	**shingle**
4d	1½	190	224	220				
5d	1¾	...	...	180	130			
6d	2	...	...	...	97		120	
7d	2¼	...	...	...	85		94	
8d	2½	...	...	...	68		74	90
9d	2¾	...	...	...	58		62	72
10d	3	...	...	...	48		50	60
12d	3¼	...	...	...	...		40	
16d	3½	...	...	...	...		27	

Characteristics of Open Hearth Basic Steel.—(Kidder.)

Percentage of Carbon	Tensile Strength in lb. per sq. in.		Ductility	
	Ultimate Strength	Elastic Limit	Stretch in 8 in.	Reduction of Fractured Area
.08	54000	32500	32 percent	60 percent
.09	54800	33000	31 ‘‘	58 ‘‘
.10	55700	33500	31 ‘‘	57 ‘‘
.11	56500	34000	30 ‘‘	56 ‘‘
.12	57400	34500	30 ‘‘	55 ‘‘
.13	58200	35000	29 ‘‘	54 ‘‘
.14	59100	35800	29 ‘‘	53 ‘‘
.15	60000	36000	28 ‘‘	52 ‘‘
.16	60800	36500	28 ‘‘	51 ‘‘
.17	61600	37000	27 ‘‘	50 ‘‘
.18	62500	37500	27 ‘‘	49 ‘‘
.19	63300	38000	26 ‘‘	48 ‘‘
.20	64200	38500	26 ‘‘	47 ‘‘
.21	65000	39000	25 ‘‘	46 ‘‘
.22	65800	39500	25 ‘‘	45 ‘‘
.23	66600	40000	24 ‘‘	44 ‘‘
.24	67400	40500	24 ‘‘	43 ‘‘
.25	68200	41000	23 ‘‘	42 ‘‘

RESULTS OF TESTS MADE IN 1902 ON EFFECT OF CONTINUOUS MIXING OF PORTLAND CEMENT MORTARS BY C. G. STREELS, ASSISTANT CITY ENGINEER, SIOUX CITY.

Sand through sieve of 20 meshes per lin. inch and retained on sieve with 30 meshes per lin. inch; 99 oz. of cement, 220 oz. of sand and 24 oz. of water, or 7.77 per cent of the cement and sand.

No. of Briquettes	Continuously mixed for hrs.	min.	Average tensile strength lbs. per sq. inch
4	0	15	294
2	0	30	278
2	0	45	282
2	1	00	243*
2	1	25	275
2	1	55	283
2	2	25	287*
2	2	55	314
2	3	25	326*
2	3	55	372
2	4	25	334†
2	4	55	384
2	5	25	264
2	5	55	249
2	6	25	308*
2	7	25	217
2	8	25	255
4	8	55	236
4	8	55	220*
2	8	55	215*

* 2 oz. water added. † 3 oz. water added

COMPRESSIVE STRENGTH OF CONCRETE AND MORTAR COLUMNS, PLAIN AND REINFORCED, WITH LONGITUDINAL STEEL BARS—*Continued.*

NORMAL DIMENSIONS 12 IN. BY 12 IN. BY 8 FT STRENGTH.

Sectional Areas			Weight of Concrete per cubic foot	Compressive		Description
Gross	Concrete	Bars		Total	Per sq. in. in gross area.	
			Pounds	Pounds	Pounds	
159.64	......	....	135.0	800000	5011	Ultimate strength not ascertained; maximum load of testing machine applied without rupturing the column.
158.00	......	....	144.1	271000	1720	Oblique cracks.
158.25	155.94	2.31	144.1	458000	2890	" "
157.12	... ..	....	143.2	278000	1769	Longitudinal cracks.
160.40	158.09	2.31	142.2	322000	2010	Oblique cracks.
159.39	......	....	147.6	272000	1710	" "
157.62	155.37	2.25	143.7	313000	1990	Longitudinal fractures.
159.76	158.21	1.55	145.7	349000	2180	Longitudinal cracks.
159.64	159.99	1.65	145.4	318000	1990	" "
159.50	153.00	4.50	143.5	497000	3160	General direction of cracks longitudinal.

159.52	156.43	3.09	146.9	452000	2830	Longitudinal and oblique cracks.
158.50	155.19	3.31	146.4	438000	2760	Longitudinal fractures.
159.39	157.08	2.31	143.1	289000	1820	Longitudinal and oblique cracks.
159.26	......	....	151.2	278705	1750	....
159.39	......	....	103.7	138900	871	Oblique cracks.
159.39	157.08	2.31	106.3	334000	2095	" "
160.27	......	....	139.8	74000	462	Irregular longitudinal cracks.
160.00	157.69	2.31	139.5	218600	1370	Rods bulged outwards.
159.39	156.30	3.09	148.8	365000	2290	Longitudinal cracks, rods bulged outwards.
159.63	......	....	154.4	75200	471	....
......	......	....	....	215000	1350	After rest of four months.
160.27	157.18	3.09	154.0	192324	1200	Ultimate strength not ascertained.
......	......	....	....	425000	2650	After rest of four months.

COMPRESSIVE STRENGTH OF CONCRETE AND MORTAR COLUMNS, PLAIN AND REINFORCED, WITH LONGITUDINAL STEEL BARS.

NORMAL DIMENSIONS 12 IN. BY 12 IN. BY 8 FT. STRENGTH.

Composition				Age		Reinforcing Bars	
Cement	Sand	Stone or Cinder	Kind of Stone or Cinder	Months	Days	Number and Kind	Per cent of Metal
1	1	..	....	6	..	None	..
1	1	2	½–1½ in pebbles	7	28	“	..
1	1	2	“ “	8	..	4 ¾ in. twisted	1.46
1	2	3	“ “	7	25	None	..
1	2	3	“ “	7	28	4 ¾ in. twisted	1.44
1	2	4	“ “	3	17	None	..
1	2	4	“ “	3	13	4 ¾ in. twisted	1.43
1	2	4	“ “	3	16	4 ⅝ in. corrugated	0.97
1	2	4	“ “	3	14	4 ¾ in. Thacher	1.03
1	2	4	“ “	3	15	8 ¾ in. twisted	2.86
1	2	4	“ “	3	14	8 ⅝ in. corrugated	1.94
1	2	4	“ “	3	12	8 ¾ in. Thacher	2.09
1	2	4	“ “	7	26	4 ¾ in. twisted	1.45
1	2	4	½–1½ in. trap rock	5	10	None	..
1	2	4	Cinders	5	16	“	..
1	2	4	“	5	16	4 ¾ in. twisted	1.45
1	3	6	½–1½ in. pebbles	7	23	None	..
1	3	6	“ “	7	24	4 ¾ in. twisted	1.44
1	3	6	½–1½ in. trap rock	5	10	8 ⅝ in. corrugated	1.94
1	3	6	“ “	..	7	None	..
1	3	6	½–1½ in. trap rock	..	7	8 ⅝ in. corrugated	1.92

Quantities of Ingredients Necessary to Form one Cubic Yard of Concrete of Various Proportions.

Proportions of Ingredients	Quantities necessary to make 1 cubic yard of concrete in place				Proportions in cubic ft. of aggregate per bag of 224 pounds of cement	
	Barrels of cement, weight 376 lbs.	Cement, pounds	Sand cubic feet, measured loose	Stone, cubic feet measured loose	Sand cubic feet	Stone, cubic feet
1:1 :2	2.75	1034	10.45	20.90	2.26	4.52
1:1½:3	2.00	752	11.40	22.80	3.40	6.80
1:2 :4	1.57	590	11.88	23.76	4.90	9.80
1:2½:5	1.29	485	12.21	24.42	5.64	11.28
1:3 :6	1.10	414	12.48	24.96	6.76	13.52
1:4 :8	0.85	320	12.60	25.20	8.82	17.62

THACHER ROLLED BARS.

Nominal diameter, inches	Sectional area, square inch	Weight, pounds per lineal foot	Nominal diameter, inches	Sectional area, square inches	Weight, pounds per lineal foot
¼	0.047	0.16	1¼	1.10	3.74
⅜	0.10	0.34	1⅜	1.32	4.49
½	0.18	0.61	1½	1.56	5.30
⅝	0.28	0.95	1⅝	1.81	6.16
¾	0.41	1.39	1¾	2.08	7.07
⅞	0.55	1.87	1⅞	2.35	8.00
1	0.71	2.42	2	2.65	9.02
1⅛	0.90	3.06			

Thacher Bars are manufactured by the Concrete Steel Engineering Company, Park Row Buildings, New York, who also design and construct arched bridges and other works.

SIZE AND WEIGHT OF JOHNSON BARS.

Size in inches	Net section, square in.	Weight, pounds per foot run	Size in inches	Net section, square in.	Weight in pounds per foot run
¼	0.06	0.24	¾	0.56	1.91
⅓	0.11	0.38	⅞	0.77	2.60
½	0.25	0.85	1	1.00	3.40
⅝	0.39	0.33	1¼	1.56	5.31

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Expanded Metal

Size of Mesh-Width

Expanded Metal numbers

½"	¾"	1½"	2¼"	3"	6"	Area □" per 12" wid	Weight-lbs per sq ft	Elastic limit lbs per 12" width
			052¼	053		.05	.171	3600
10½	10¾	101½	102¼	103		.10	.341	6000
15½	15¾	151½	152¼	153		.15	.511	9000
20½	20¾	201½	202¼	203		.20	.681	12000
	25¾	251½	252¼	253	256	.25	.849	15000
	30¾	301½	302¼	303	306	.30	1.02	18000
		351½	352¼	353	356	.35	1.185	21000
			402¼	403	406	.40	1.36	24000

In the number the two first figures express the reinforcing area in 12-in width and the last figure the width of mesh.

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